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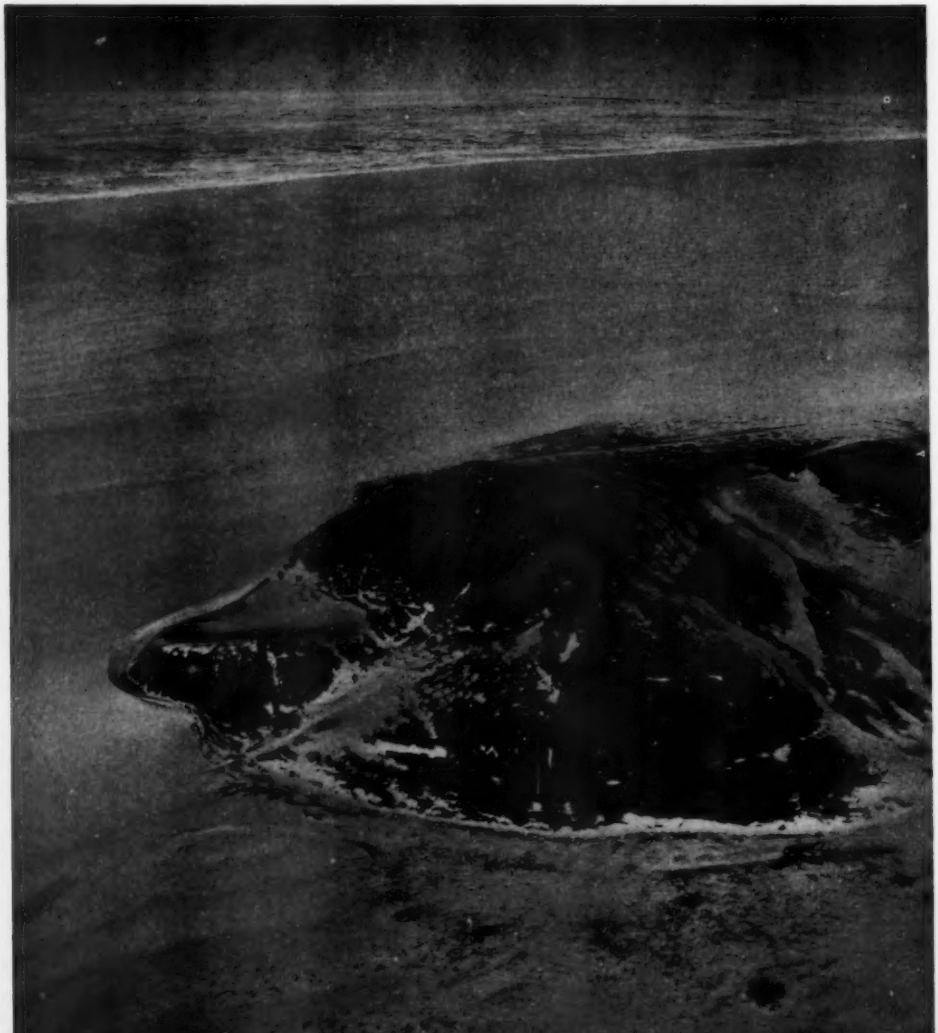

Photo: R.C.A.F.

Fig. 1. Western Ward Hunt Island. The high hill (1,400 feet) is in the middle with the lake to the right. The ice on the lake melts around the edges only; in the centre it was 14 feet thick in mid-July. The final camp was on the "ice rise" to the left; the "ice rise" to the north of the island is also visible. Dirt on the ice shelf is mainly wind-borne and stream-borne material. In the distance the edge of the ice shelf and the polar pack can be seen. 4 July 1953.

NORTHERN ELLESMERE ISLAND, 1953 AND 1954*

G. Hattersley-Smith† and other members of the expeditions

THERE have been few travellers in northern Ellesmere Island, and, until the present investigations, work in this region had been mainly exploratory. The following account mentions briefly the early visits and describes the journeys made by the expeditions of 1953 and 1954. Short appendices record some of the preliminary results in the fields of glaciology, geophysics, oceanography, and geology.

In 1876 Aldrich and his sailors, in the man-hauling tradition of those days, made a great sledge journey westward to Alert Point from Cape Sheridan, the winter quarters of the *Alert* (Captain Sir G. S. Nares, R.N.). Markham, of the same expedition, travelling northward from Cape Joseph Henry, reached latitude 83°20N., after the most arduous relaying over mountainous pressure ice, and Egerton journeyed up the valley of Wood River, southwest of winter quarters, to within sight of the ice cap of the United States Range. The members of the sledge parties, with few exceptions, suffered severely from scurvy, which caused the loss of two of the *Alert*'s men and the abandonment of Nares's plans for a second season (*Parliamentary Paper*, 1877; Nares, 1878; Feilden and De Rance, 1878).

From 1881–4 Greely led the United States expedition to Lady Franklin Bay, spending two winters at Fort Conger on Discovery Harbour, and a third winter in disastrous retreat at Cape Sabine. In 1882 Pavey, Rice, and an Eskimo went north by the coastal route from Fort Conger trying to better Markham's "furthest north", but were forced back by open leads a few miles north of Cape Joseph Henry (Greely, 1886).

On his expedition of 1898–1902 Peary took up the quest for the north pole, which occupied him for the next decade. In 1902 he made his first foray along the north coast of Ellesmere Island, travelling from his base at Fort Conger with Greenlandic dog drivers. From Cape Hecla he turned north and reached latitude 84°17N., before being forced to return (Peary, 1907). On his 1905–6 expedition Peary wintered his ship, the *Roosevelt*, at Cape Sheridan. In the spring of 1906 he left land at Point Moss, and journeyed north to latitude 87°06N., before being forced back on the Greenland coast near Elison Ø. Only a few days after returning to his ship, Peary set out for the west with the intention of passing Aldrich's "farthest", and visiting the

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†Arctic Section, Defence Research Board of Canada.

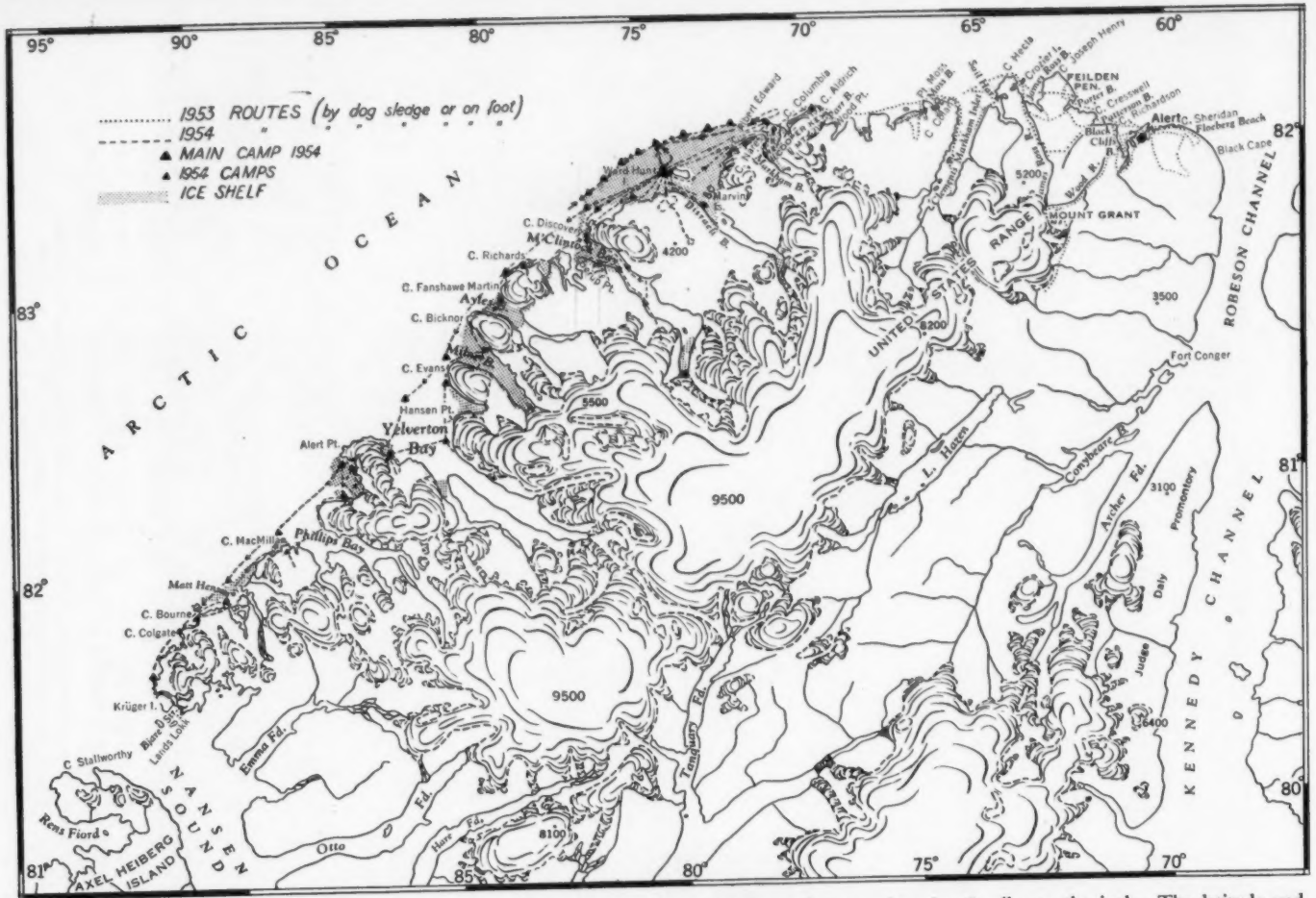

Fig. 2. Northern Ellesmere Island showing routes of the 1953 and 1954 expeditions: scale approximately 40 miles to the inch. The latitude and longitude of the sketch-map have not been adjusted in accordance with sun-shots taken in 1954 as the extent of the coastline affected is not known.

unexplored coastline beyond to the northern limit of the survey of the Second Fram expedition (1898–1902) which had worked north up Nansen Sound. In this Peary was successful, and in fact reached "Cape Thomas Hubbard" (now Cape Stallworthy), the northern tip of Axel Heiberg Island. The journey back to Cape Sheridan in the height of the thaw season was probably the hardest Peary ever made (Peary, 1907). Peary "was ever a fighter", and in 1908 he again sailed north in the *Roosevelt* to winter quarters at Cape Sheridan, and in the following April attained his ultimate goal. On the north polar journey he travelled over the ice from Cape Columbia, where a large depot of stores had been laid by repeated sledge journeys from the expedition's winter quarters in the preceding months. Small depots were also placed as far west as Cape Fanshawe Martin, for possible use by returning parties caught by a westerly drift (Peary, 1910).

The north coast of Ellesmere Island was not visited again until 1920, when Comdr. Godfred Hansen on the Third Thule expedition laid depots at Fort Conger, Cape Richardson, and Cape Aldrich[1], in support of Roald Amundsen's north polar drift in the *Maud*. Hansen made the long journey from Thule by dog team with Greenlandic drivers (Hansen, 1921).

The Lands Lokk area to the west was briefly visited in 1930 by H. K. E. Krüger and his two companions of the lost German expedition. They had journeyed north from Neqe, in northwest Greenland, via Bay Fiord and Nansen Sound, and later reached Cape Stallworthy, where their record was found by Cpl. H. W. Stallworthy on the search expedition of 1932. Their subsequent fate is unknown (*Polar Record*, 1934).

In 1935 the Oxford University Ellesmere Land expedition, based on Etah, sent one party by way of Fort Conger and Lake Hazen into the mountains of northern Ellesmere Island. A. W. Moore and the Greenlander Nukapinguaq reached a height of 9,000 feet, whence they had a view of the unknown land as far as the ice of the Arctic Ocean at Clements Markham Inlet on the north coast (Moore, 1936, p. 425).

It was not until after the Second World War that the U.S. Navy icebreaker *Edisto* and the U.S. Coastguard icebreaker *Eastwind* in 1948 reconnoitred the northeast coast of Ellesmere Island as far west as Cape Belknap, where a cache was laid for a future weather station. Two years later the weather station, Alert, was established just south of the cape.

In 1951 P. F. Bruggemann and S. D. MacDonald studied the biology around Alert, and made a trip up Wood River almost to the ice cap (Bruggemann and Calder, 1953; MacDonald, 1953). The next year P. Gadbois and C. Laverdière carried out a geographical survey within a 10 to 15 mile radius of the weather station (Gadbois and Laverdière, 1954).

In 1946 the discovery that huge floating ice masses, later known as ice islands, existed in the Arctic Ocean gave rise to speculation on their origin and possible strategic value. Subsequent flights and the study of air photographs strongly suggested that the ice shelf along the northern coast of Ellesmere Island was the most likely source area (Koenig *et al.*, 1952). On 19 March

[1]The Danes referred to this as the Cape Columbia Depot.

Fig. 2. Northern Ellesmere Island showing routes of the 1953 and 1954 expeditions; scale approximately 40 miles to the inch. The latitude and [illegible] have been adjusted in accordance with corrections resulting from the 1954 re-survey of the coastline affected is not known.

1952 the U.S. Air Force made the first landing on the ice island T3 to set up a weather station, which became a base for research in oceanography, hydrography, glaciology, and geophysics until May 1954 when the station was temporarily abandoned.[1] Flying from T3 in May 1952, Lt. Col. J. O. Fletcher, Lt. Col. W. P. Benedict, and A. P. Crary landed briefly on the Ellesmere Ice Shelf near Ward Hunt Island to examine the shelf, and at Cape Aldrich, farther east, to examine the Peary monument of 1909 and the Hansen cache of 1920 (Fletcher, 1953; Rodahl, 1953).

It seemed logical to follow up the work on T3 with a complementary program on the probable parent ice mass. The Defence Research Board of Canada, therefore, planned a reconnaissance in 1953, in cooperation with the Geological Survey of Canada, to prepare the way for detailed work on the ice shelf in 1954. It had been hoped that the U.S. Air Force Cambridge Research Center and the Snow, Ice, and Permafrost Research Establishment, Corps of Engineers, U.S. Army, which had sponsored the geophysical and glaciological studies respectively on T3, would participate, but, unfortunately, owing to prior commitments this was not possible in 1953. By great good fortune the 1954 party included A. P. Crary, geophysicist from A.F.C.R.C., and E. W. Marshall, glaciologist from S.I.P.R.E., both experienced men who between them had spent a total of more than twenty months on T3. The Geological Survey of Canada was interested in obtaining geological data from this almost unknown region and their officers—R. G. Blackadar in 1953, and R. L. Christie in 1954—not only made valuable contributions in their own field, but were also extremely helpful in other fields of study.

The expeditions of both years are grateful to the U.S. Air Force for the necessary logistic support, and to the Controller of the Canadian Meteorological Service and the staff of Alert Weather Station for the facilities and hospitality provided. Through the courtesy of the Danish authorities it was possible to enlist two Greenlanders who served as dog drivers for the first two months of each season. They were Rasmus Majak and Sigssuk in 1953, and Imina and Karkutirak in 1954.

The 1953 expedition

In 1953 Blackadar and I were flown by the U.S. Air Force from Ottawa via Westover Air Force Base to Thule, where we arrived early on April 21. After picking up Rasmus Majak and his thirteen dogs, we continued to Alert, landing late that afternoon. Over 7,000 lb. of food and equipment had preceded us; most of this weight consisted of frozen horse meat as dog pemmican was not available. It soon became apparent that Majak was unwilling to accompany us on more than a day's trip from Alert without a Greenlandic companion; he remembered that Ahqioq had been the only Greenlander on the Krüger expedition, and had not come back. This seemed to us a very reasonable point of view, and we requested the Danish authorities for the

[1] A small United States party, under the leadership of A. P. Crary, reoccupied the station in April 1955.

services of another Greenlander. 'Sigssuk arrived with six more dogs on April 28, and the following day we left with the two dog teams for the west by the coastal route, made historic by the journeys of Aldrich and Peary.

Our progress along the north coast as far as Point Moss was hindered by the rough pack ice and hummocky bay ice and the soft, often deep, snow which made it impossible for the dogs to haul more than about 600 lb. per komatik. Although we planned to be away from Alert for only about three weeks, the weight of the horse meat, three times that of an equivalent amount of dog pemmican, enforced relaying for the first part of the journey.

It was not, therefore, until May 11 that we reached Cape Columbia on our way to the main development of the ice shelf, which starts in Markham Bay west of Cape Columbia. Up to this time we spent the first nine hours or so of each day travelling, and geological work and ice and snow cover measurement had to be done after camping. We left food depots along the way to be used on the return trip.

Between Alert and Cape Columbia we visited three cairns left by previous expeditions. On View Hill (Feilden Peninsula) there stands the cairn built by Aldrich in 1876 and visited by Pavey in 1882, who removed Aldrich's record and left his own; we found nothing in the cairn. On the highest point of Crozier Island we visited the huge cairn built by Aldrich on his outward journey to Alert Point (*Parliamentary Paper*, 1877, p. 188). It was heavily banked with snow at the time of our visit on May 6, but on a subsequent visit Aldrich's record of 18 April 1876[1] came to light, somewhat discoloured in a rusty tin canister. The third cairn was a dismantled one at Cape Colan, which doubtless marked the site of the depot left at this point by Aldrich in 1876 or Peary in 1909—or of both.

On May 11 we made camp on the ice-foot at Cape Aldrich and walked up the low headland to look at the Peary signpost nearby. The upper part of the post was broken off, and the board with Cape Columbia inscribed and the arm pointing to the north pole were hanging down. The arms were still stayed by the wires shown in Peary's photograph (Peary, 1910, *facing* p. 324). Lashed to the post were the ski and ski-pole left by Fletcher, Benedict, and Crary when they landed here in 1952 (Fletcher, 1953; Rodahl, 1953). An earthenware jar was standing at the foot of the cairn; although the lid was tightly clamped down, the rubber washer had perished and water had reduced the paper inside to pulp.

Two hundred yards west of the signpost we could see the broad komatik runners marking Hansen's cache, half buried in the snow. The cache contained a primus stove in a tin; a can of kerosene; two cases of sledge-rations put up by Beauvais of Copenhagen, with about half the food in good condition; a very fine shotgun-rifle in a tin box with cartridges by Kynoch and rifle shells; a crow-bar; and, most interesting of all, a small tin box containing Godfred Hansen's records, the plans for the depot journey to Cape Columbia, signed by Knud Rasmussen, and mail, all addressed to Captain Roald Amundsen (Fig. 4). All the papers were carefully wrapped in oiled silk, and were in as

[1]*See* p. 33.

perfect condition as on the day they were left. With the papers were two pairs of snow-goggles by Cornelius Knudsen of Copenhagen (Hansen, 1921).

On May 12 we mended the signpost and fixed Peary's broad runners from the cache to one of our komatiks to speed us on our return trip. In the afternoon Blackadar and I fixed marker poles on a remnant of the ice shelf in Parr Bay. The next morning in light drift and low visibility the whole party ascended the 1,800-foot eastern peak of Cooper Key Mountain. Unfortunately, there was no view from the summit, which was in cloud, and a 40-knot wind was blowing, but we found Peary's massive cairn with the broken stump of the ash stave he had fixed there. Near the top of the cairn, slipped into a crevice, was a small cocoa tin, the lid of which opened easily. Inside was the piece of Peary's north polar flag and the record which he had deposited on 8 June 1906 (Peary, 1907, p. 183; for facsimile of record *see* Stafford, 1954, p. 525).

On May 14 we visited Markham Bay (Fig. 3), following the ice-foot round Cooper Key Mountain before going out on the sea ice. Across the ice shelf in the mouth of the bay I aligned survey poles to act as movement and ablation markers, while Blackadar studied the geology. The tremendous rampart of blue ice blocks along the ice-foot of Cape Columbia rises to 40 feet, and testifies to the great driving force of the polar pack. Next day we were tent-bound at Cape Aldrich by a blizzard, with wind gusts up to 50 knots. On May 16 we set out for Alert. During the return trip, which took five days, we made a detour 5 miles down Clements Markham Inlet for geological work; there, a small and evidently starving hair seal on the ice provided one fresh meal for the dogs.

We left Alert again on May 27 for the small bay southwest of Point Moss to study the remnant of ice shelf in the bay and the local geology. On this occasion we followed the ice-foot around Cape Hecla, instead of taking the Sail Harbour route to Cape Colan as before, and the journey took four and a half days, including one day lying-up because of bad weather. On the return trip we made a detour 25 miles down Clements Markham Inlet, where we left a food depot for possible use later in the season. We arrived back at Alert on June 9.

Between June 12 and 15 we were away from Alert in the Cape Sheridan region making geological observations. During this time we laid a depot 12 miles inland from Floeberg Beach, backpacking for the last 4 miles the food which we planned to use later in the summer. There are cairns or monuments above Floeberg Beach commemorating the "British Arctic expedition" (1875–6), Niels Christian Petersen (d.1876), the *Roosevelt* (1905–6: two cairns), Ross G. Marvin (d.1909), and the U.S. Navy and Coast Guard (1950).

The Greenlanders were now extremely anxious to return to Thule for the summer hunting and there followed a frustrating, though unavoidable and not unpleasant, period of two weeks at Alert, waiting daily for an aircraft to take them out. They finally left on July 2, and the next day Blackadar and I departed on foot for Wood River and the United States Range, carrying loads of about 80 lb. each.

Fig. 3. Looking west across Markham Bay to Cape Nares. The faulted Permo-Carboniferous limestone unconformably overlies steeply dipping gneissic rocks. 2 May 1954.

Photo: Geol. Surv. Can.

Fig. 4. Majak, Sigssuk, and Hattersley-Smith examining the cache left by Godfred Hansen at Cape Aldrich. 12 May 1953.

Photo: Geol. Surv. Can.

Fig. 5. The United States Range, looking west from 10 miles south of the head of Wood River. Saxifrage growing in foreground; piedmont glacier in background. 11 July 1953.

The ice in Black Cliffs Bay was in a very puddled condition; in fact we crossed it just before it went out—a few days later and we would have had a long walk round the head of the bay. At the mouth of Wood River we picked up food from a cache laid by dog team in May. To reach this cache, which was on the north side of the river, we had to make a tricky fording of the thigh-deep, fast-flowing stream; we then threw the food across to our campsite on the south side.

On the afternoon of July 5 we started making our way up Wood River, carrying about 60 lb. each. The setting for this walk was delightful. In perfect weather we passed groups of muskoxen grazing amid purple saxifrage and yellow poppies, and glimpsed the snowclad mountains to the southwest. But the scrambling up and down the rocky spurs along the south side of the river with heavy packs marred our enjoyment. After averaging about 12 miles a day, we made our final camp a mile from the first big glacier lobe at the head of Wood River valley on July 7 (Fig. 5). We spent the next six days in trips to the glaciers nearby for snow and firn measurements, in an ascent of Mount Grant, 5,600 feet, and in a walk to the very large ice lobe 20 miles south of camp. Here we found Tertiary deposits with coal and plant remains near the 100-foot ice-cliff.

The weather deteriorated on July 13, and we left camp in light snow, reaching the mouth of Wood River next day. On the 15th, after a leisurely breakfast of scones cooked over an open fire of driftwood and muskox dung, we set out on a four-day trip up "Patterson River",[1] over the divide to the west, and back by "James Ross River", Feilden Peninsula, Porter Bay, and Cape Cresswell in overcast weather, with occasional light snow or sleet. On this trip Blackadar collected geological data, much of which had been obscured by snow on our earlier trips. We did not use our Clements Markham Inlet depot. We arrived back at the mouth of Wood River on July 18, and reached Alert the following day, after walking round the head of Black Cliffs Bay. We had covered over 300 miles during the seventeen days we had been away.

In the last days of July we attempted to walk to Fort Conger, using the food depot we had laid in June, but were foiled by bad weather and poor visibility. We contented ourselves with visiting an old camp, 12 miles south of Cape Sheridan, established by Giffard and Conybeare on 7 July 1876 (Conybeare, 1930, pp. 134–5) and discovered by John Lewis, Officer-in-Charge Alert Weather Station 1950–1 and 1953. We brought back two sleeping bags, some clothes, a pair of canvas boots, a thermometer, and a first aid kit.

Bad weather now set in, and, except for a three-day trip to Black Cape over the first snow of winter, we remained at Alert packing our equipment. We left by air on August 16 for Thule and the south.

The 1954 expedition

In 1954 Crary, Marshall, Christie, and I, with the Greenlanders Imina and Karkutirak, and twenty-four dogs, made our main camp on the ice shelf near Ward Hunt Island (Fig. 6), where we landed on April 24 in two ski-wheel C47 aircraft of Northeast Air Command. The first aircraft was piloted by Col. B. Hansen, Deputy Commander of Thule Air Base, and Col. W. L. Kimball, Commander of Thule Air Base, flew in with the second aircraft. We had food with us for several weeks and enough equipment to enable us

[1]Place names given in quotation marks are new names which have been submitted to the Board on Geographical Names but have not yet been adopted.

Fig. 6. The main camp on the ice shelf, looking south. 28 April 1954.

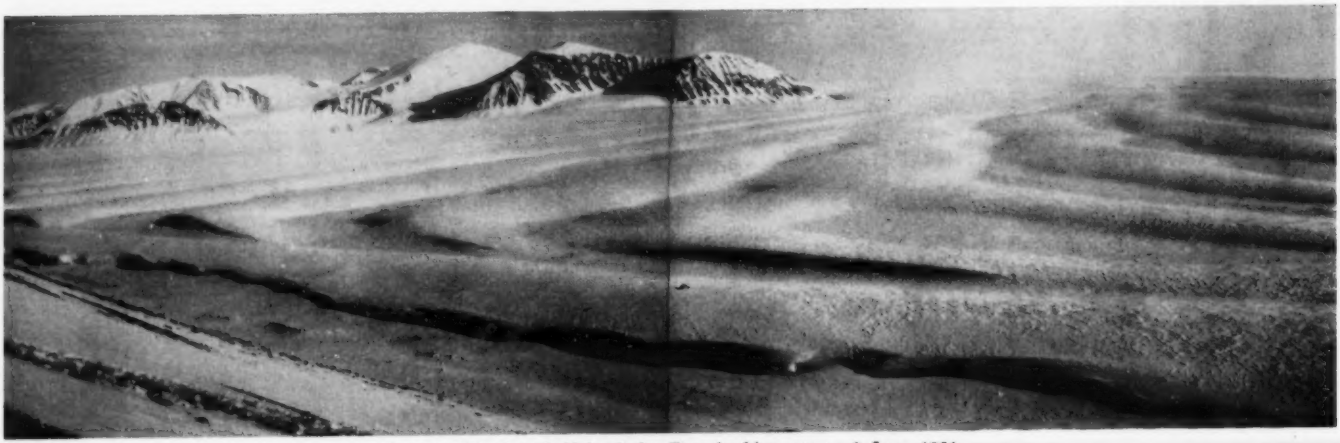

Fig. 7. The ice shelf in Ayles Bay, looking west. 3 June 1954.

to start work at once; the remainder of our food and equipment was to be brought in when weather permitted. The evening was calm and clear, with the temperature about zero, and the aircraft took off immediately after unloading. The next day a blizzard set in and lasted for two days, but we were well installed in our two pyramid and two mountain tents, with our food and equipment piled up outside.

On April 29 Marshall, Christie, and I with the Greenlanders went on a two-day trip to Cape Albert Edward; Christie made a geological traverse and Marshall and I took snow depth, density, and temperature measurements on the glacier south of the cape. While we were away, two more aircraft loads of food and equipment were flown in.

On May 2 Christie and I and the two Greenlanders left for Cape Columbia. The first night we camped in the middle of Markham Bay, and the following day, while Christie and Karkutirak travelled down Markham Bay to study the geology, Imina and I checked on the poles set up in 1953. Christie and Karkutirak had heavy going due to the deep soft snow a few miles south of camp, and the very steep sides of the troughs on the ice shelf in the fiord; they did not return until late afternoon. An hour later we left Markham Bay, and made camp that evening half a mile from the Peary signpost at Cape Aldrich. On May 4, with one dog team, we visited Parr Bay and recovered Hansen's note[1] from MacMillan's tide-gauge cairn, 3 miles south of Cape Aldrich at the site of "Crane City", Peary's advance base for the polar journey. The site was marked by broken sledges, boxes, and rusty tins. Unfortunately the iron pipe, the tip of which was the index mark of the tide gauge, had fallen down and so was worthless for further observations. While Christie and Karkutirak did geological work in Parr Bay, visiting Wood Point, I searched unsuccessfully for my poles set up in 1953 on the remnant of ice shelf in Parr Bay. We spent another day making observations near Cape Aldrich, and started back on May 6. The thick snow of the previous day slowed us down, after we had left the ice-foot of Cape Columbia, and we were eventually obliged to camp about 7 miles east of Ward Hunt Island. We reached the main camp just before noon the following day.

Fig. 7. The ice shelf in Ayles Bay, looking west. 3 June 1954.

While we were away, Crary and Marshall had succeeded in coring a hole to a depth of nearly 80 feet in the ice shelf at the campsite. On May 8 we installed thermocouples at various depths in this deep hole. Next day, Crary and Christie with Imina set off down Disraeli Bay (Fig. 8) to map the geology and to take soundings, but they were forced to turn back near the mouth of the bay because of deep soft snow, for which the fan-style of dog driving is quite unsuitable. Even on skis travel was difficult. Meanwhile Marshall set up camp near the edge of the shelf north of the main camp to take ice cores.

It was at this time that Karkutirak informed me that he wished to go back to Thule for the hunting. Imina now seemed uncertain whether he, too, might not want to return before the end of the summer; he was definitely unwilling to stay unless another Greenlander came in to replace Karkutirak. Provided they would leave us enough dogs, it seemed best for both to go back to Thule

[1] *See* p. 34.

Photo: R.C.A.F.

Fig. 8. Looking south into Disraeli Bay at the beginning of the thaw season, showing the "Marvin Islands" at the entrance of the bay. Near the small island 10 miles from the entrance no bottom was recorded at 300 metres. 4 July 1953.

on the first available aircraft. Karkutirak kindly agreed to leave us ten of his twelve dogs and Imina agreed to leave four of his. We had the greatest regard and friendship for the Greenlanders, and fully appreciated their point of view.

Christie and I now started making preparations for our trip to the west; we would drive Karkutirak's dogs on this journey. In our absence Crary would go ahead with survey work and levelling on the ice shelf, while Marshall carried on his ice petrology.

Christie and I started west in perfect weather on May 14, intending to be away between twenty-one and twenty-four days. We carried a load of about 600 lb. on the komatik. Our plan was to reach Lands Lokk as fast as possible, cutting straight across the mouths of the deep fiords and travelling, for the most part, at some distance from the land. We would take longer on the return trip and make detours into the fiords for geological work.

The surface was good and we covered about 25 miles per day crossing Alert Point on May 18, the same date that 78 years earlier Aldrich had reached

July 5th 1906

Arrived here 4 - a.m.; June 24th
from the Peary Arctic Club's
Steamer Roosevelt, which win-
tered at C. Sheridan.

Have been busy across the
Channell to the west land to the
north.

Am now returning to
the Roosevelt. Delayed here now
two days by stormy weather.

Expect to start in an hour
or two.

The ice in every direction
flooded deep with water.

R. E. Peary, U.S.N.

Figs. 9 and 10. Peary record and cairn at Cape Colgate. Christie beside cairn, 22 May 1954.

Alert Point, his "farthest" (*Parliamentary Paper*, 1877, p. 213). On the point we noticed two caribou, which, with one seal in Phillips Bay on the way back, were the only game seen on this trip. From Cape Bourne onward, and throughout the return journey, Christie did geological work during the day, while I drove the dogs to some agreed campsite, where we met in the evening. At Cape Colgate we recovered Peary's record of 5 July 1906 from the cairn 200 feet above the shore (Figs. 9 and 10) (Peary, 1907, p. 219). The following day we made camp close to the westernmost point of the coastline. Nearby was a Peary cairn in which we found Krüger's record of 22 April 1930, soldered into a tin (Figs. 11 and 12) (*Polar Record*, 1934). On May 23 Christie and I walked down to Lands Lokk, leaving the dogs in camp.

On the return trip to the main camp, which took fourteen days, Christie completed the geological reconnaissance of the north coast of Ellesmere Island, and I made glaciological observations and brought back two 10-foot ice cores from the remnant of ice shelf west of Alert Point. At Cape Fanshawe Martin we kept a sharp lookout for Aldrich's cairn, but there was no sign of it from the shore or from the sea ice. Later I climbed the most likely looking hill, rising 300 feet above the shore, and there on top was the massive cairn, invisible from below because of the convexity of the slope. Aldrich's tin canister was found after some of the upper blocks of the cairn had been removed. It

Die Deutsche Arktische Expedition,
von Herke in Nordgrönland durch Bag-
Fjord kommend, erreichte am 22. April 1930
diesen von Peary erbauten Steinmann
(kein Bericht vorgefunden).

Wir gehen weiter zum Nordspitze
von Heiberg-Land. Ein Schlitten, 14 Hunde
und drei Mann in gutem Zustande.

Åge Rose Bjare
A h q i 09

H. K. E. Krueger
Leiter

Fig. 11. Record left by Krüger, four miles west of Cape Colgate.

Photo: R.C.A.F.

Fig. 12. Lands Lokk region looking southwest across Nansen Sound to Cape Stallworthy on Axel Heiberg Island. The arrow indicates the position of the cairn containing the Krüger record. "Bjare Strait" and "Krüger Island" are shown. A small ice island is just visible near the middle of the picture. 16 July 1950.

contained the record and copy of his chart[1] packed in a small inner canister, set in candle wax (*Parliamentary Paper*, 1877, pp. 216–7); both were excellently preserved. Shortly after leaving Cape Fanshawe Martin we picked up a tin of candy bars on the ice-foot, kindly dropped towards the end of April by the Royal Canadian Air Force for the benefit of any chance passers-by.

We arrived back at the main camp on June 6, to find Crary and Marshall in good spirits. Crary had been filling the time with survey, meteorological, and tidal observations, and Marshall had been very busy with his glaciological work. They had started levelling on the shelf over the 12 miles between land and the seaward edge and during the next week we completed this work.

Christie and I were surprised to find that the Greenlanders had not yet gone out. On June 15 it was decided that they should leave by dog team for Alert, since the ice shelf was in poor condition for landing. They reached Alert a week later, after a fairly hard trip through deep snow, and were flown by a C47 aircraft on the following day to near Kanak on the Greenland ice cap, whence they sledged down to their homes.

[1]*See* pp. 34 and 35.

On June 15 Crary and I also left, with ten dogs, for the edge of the shelf to start the oceanographic program. In the course of the next week we obtained depths and bottom cores at eleven stations between the meridian of the main camp and that of Cape Discovery; at two of the stations we observed ocean temperatures and collected water samples for salinity determination. In the meantime Marshall and Christie set out on skis for M'Clintock Bay, with four dogs hauling a small pulka, to make a geological and glaciological reconnaissance up the western arm of this big fiord.

Crary and I returned to camp for one day, on June 24, to gather the last of the stores and equipment which had been dropped by Northeast Air Command the previous day. They had kindly included a case of oranges, a case of apples, and two cases of fresh meat which were most welcome. We then went back to the edge of the shelf, and headed eastward to obtain stations as far as Markham Bay. This trip resulted in eight more hydrographic stations, at one of which temperatures and water samples were also taken.

We returned to the main camp on July 1, and Marshall and Christie arrived from M'Clintock Bay three days later after a hard trip due to the thaw, which was now well advanced. There were blue lakes in the troughs and the snow on the ridges was slushy. Owing to the rapidity of the thaw Crary and I had had to leave our radio at the edge of the ice shelf. Therefore, on July 6, Crary, Marshall, and Christie, man-hauling a small pulka, travelled north to the radio to keep the pre-arranged schedule with Alert. At first they attempted to find ways round the trough lakes, but soon gave this up and waded through them. They made the trip in about eight hours, contacted Alert the following day, and came back to the main camp, through the forty-seven trough lakes, on July 8, after safeguarding the equipment left at the edge of the shelf.

We now decided to establish a temporary camp on Ward Hunt Island, and from July 11 to 20 three members of the party camped there, always leaving one member at the main camp. Geological investigations, sounding in the lake near the middle of the island (Fig. 1), plant collecting, and work on the nearby part of the shelf, including tide-gauge readings, occupied us during this pleasant period on land.

After we had all moved back to the main camp, we found that it was possible to get over to the "mainland" due south by wading through twenty-six trough lakes. From July 22 to August 14 all four members of the party spent varying periods on the "mainland". The geological reconnaissance was extended inland about 15 miles, some of the glaciers were visited (Fig. 13), and plants were collected. A spell of excellent weather at the end of July made walking a real delight in air balmy at a temperature of 55°F. Observations were also made on the ice shelf in Disraeli Bay, and soundings were taken along the landward edge.

Between July 31 and August 2 three of us made the wet and tortuous journey with the dogs to the edge of the shelf to make radio contact with Alert. This was a most unpleasant trip for the dogs, whose feet were quite badly cut. We brought back the other pyramid tent and some of Crary's

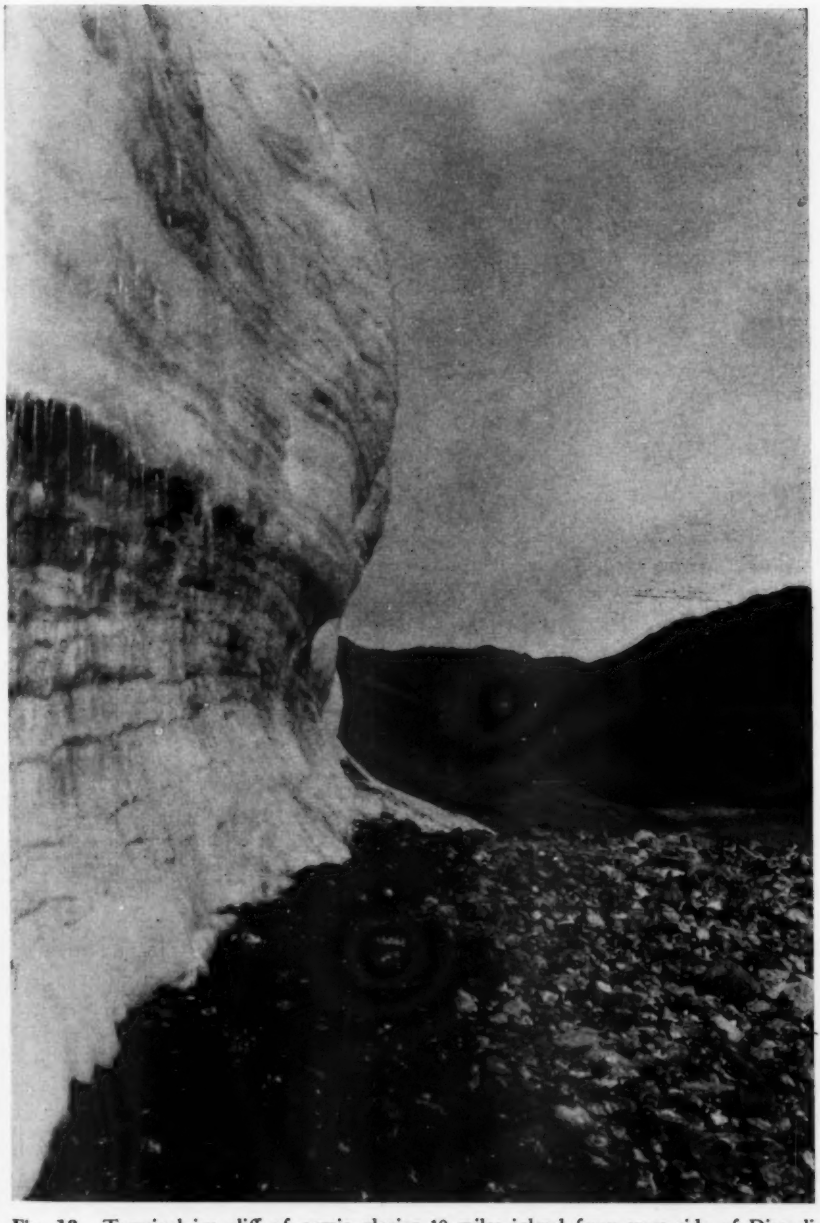

Fig. 13. Terminal ice cliff of corrie glacier 10 miles inland from west side of Disraeli Bay. The ice cliff shown is about 30 feet high, but similar vertical cliffs elsewhere in northern Ellesmere Island may be as much as 100 feet high. 29 July 1954.

Fig. 14. Looking northeast along the landward edge of the "ice rise" near the "mainland" camp. To the right is the moat of nearly fresh water between the land and the "ice rise"; in the centre is the ice moat between the "ice rise" and the ice shelf; in the background is Ward Hunt Island. 24 July 1954.

seismic equipment which had been left at the shelf edge. Crary now started seismic work along the ridge running westward from the main camp towards Cape Discovery.

By August 14 we were all at the camp together, after a period of very wet weather with several inches of rain. During the summer the shelf lost about two feet of ice from its surface by melting. For the next two weeks we eagerly awaited a final freeze-up. Our hopes rose with any tendency of the thermometer to drop, which it did on August 17, only to soar above freezing again two days later. We wanted the freeze-up for easy travel, and also so that we could start drilling for ice cores which we planned to take south with us. It is technically difficult to drill in above freezing weather and the recovered cores do not keep. The late freeze-up was also delaying the time when the aircraft could land and take us out—an event originally scheduled for September 1, but which became daily more distant as the mercury stayed high. We have since found that the summer of 1954 was exceptionally mild in the far north.

We decided that an aircraft would be able to land on the "ice rise"[1] on the west side of Ward Hunt Island (Fig. 14) sooner than on the ice shelf, and started moving our main camp over there. Marshall took advantage of the

[1]"A mass of ice resting on rock and surrounded partly by an ice shelf and partly by sea" (Roberts, Roots, and Swithinbank, 1955). In this case it is surrounded partly by the ice shelf and partly by the ice-free part of Ward Hunt Island.

Fig. 15. Crary on the ice shelf with sledge loaded with equipment for a seismic traverse. Looking south towards land, a few miles west of Cape Discovery. 2 September 1954.

short spell of cold weather on August 17 and started drilling a deep hole in the "ice rise", with some assistance from the rest of us. Drilling was temporarily abandoned when the temperature rose again and about August 23, during a period of thaw, Marshall found a cache left by MacMillan on the north side of Ward Hunt Island; it contained a komatik, a canister of tea, some cans of stove fuel, a small lamp-stove, and three tins of Borden's condensed milk. MacMillan's record[1] states that the cache was laid on Peary's orders for possible use by parties returning from the north (MacMillan, 1934, p. 192).

In the meantime, we could no longer put off visiting the edge of the ice shelf again to make a radio contact and, if possible, bring back the radio. So on August 21 Crary and I made a rough two-day trip northward; fortunately there was a little recent snow which, though melting, prevented the dogs from cutting their feet. Crary used this opportunity to take further oceanographic measurements at the shelf edge for comparison with his measurements in June. From September 2 to 4 Crary and I travelled to Cape Discovery and extended the seismic traverse, started earlier, to the west, taking stations about every 2 miles (Fig. 15).

By September 5, the day before the sun set for the first time, the freeze-up had truly begun, and the temperature was around 15°F. On the 7th the whole party started for Markham Bay, with four of the dogs pulling the relashed komatik left by MacMillan. We camped in the bay that evening, and spent the next two days doing seismic work on the re-entrant of the ice shelf, and

[1]*See* p. 34.

glaciological and geological work. Marshall travelled about 10 miles up the bay to obtain ice cores from the fiord ice. The return to base camp took ten hours, as a new fall of snow the previous day made travelling slow. Next day, September 11, there was a welcome mail drop from a C47.

On September 12 Christie and I drove one dog team over to land, and brought back the equipment left at the old "mainland" camp. Two days later Crary and I travelled straight down to the edge of the shelf, across the now well-frozen trough lakes, collected further oceanographic data, and brought back all the equipment remaining there. On the 17th and 18th Crary and Christie made a last trip down Disraeli Bay for geological work and to take an oceanographic station, while Marshall and I cored two holes in the ice shelf—one at an old Peary expedition campsite, discovered earlier in the summer 3 miles west of Ward Hunt Island, the other near the edge of the Ward Hunt "ice rise".

By September 19 conditions were good for landing an aircraft on the "ice rise". On that day Col. W. L. Kimball flew in a C47 aircraft and took Christie, all the dogs, and some of the equipment to Alert, and thence to Thule the next day. The remaining three of us had all packed and were ready to leave, but a week of bad weather supervened. We finally left on September 26 in a C47 piloted by Maj. J. D. Pendergrass and, after a night at Alert, reached Thule the following morning in a C54 aircraft.

Glaciological Studies. By G. Hattersley-Smith

In 1953 it was possible, for the first time, to make ground observations on the ice shelf with a general understanding of its character and extent, which came from a previous study of air photographs (Hattersley-Smith, in press); the few earlier travellers along this coast were of course denied this inestimable advantage. Unfortunately owing to logistic difficulties detailed work on the ice shelf could not be undertaken. In 1954, with the excellent support provided by Northeast Air Command, the reconnaissance of 1953 could be followed up by detailed work.

In Markham Bay, and on the remnants of the ice shelf near Cape Aldrich, and southwest of Point Moss, lines of poles were set up in May 1953 to measure change of surface level. The Point Moss region was not visited in 1954, and the poles near Cape Aldrich had evidently fallen down due to summer ablation. Of the three poles set up on the ice shelf in Markham Bay, only one was still standing on 6 May 1954, and this showed a surface increment of 3 inches of ice since 14 May 1953, due to the refreezing of meltwater. By the end of the 1954 season this pole had also been melted out. It was unfortunate that the poles were not set deeper, but nevertheless, it seems clear that, while there may be small surface increments in some years, over a period of years wastage will predominate, and will average a few inches each year. The 1954 season seems to have been unusually mild in the far north generally; at the main camp on the ice shelf, 3 miles west of Ward Hunt Island, 24 inches of ice were lost from

the surface by melting. That there has been no net accumulation on the ice shelf for at least the last 45 years was confirmed by the finding of a Peary expedition campsite on the surface of the shelf, 3 miles south of the main camp.

Theodolite observations on the pole in Markham Bay from a cairn on shore showed that there had been no noticeable mass movement of the ice shelf one way or the other along the line of the fiord between May 1953 and September 1954. Our observations were accurate enough to detect a movement of five feet.

The cores collected from the ice shelf indicate that the upper part of the shelf was built up by annual increments of water-saturated firn or by refrozen meltwater. It seems that temperature conditions during build-up cannot have differed greatly from those prevailing at the present time. The lower part of the ice shelf has probably been formed from the freezing of sea water, but to what extent this has taken place is not known. In 1954 it was apparent that about 20 feet of ice had formed by the freezing of sea water in the re-entrant of the shelf off Markham Bay, where a large ice island photographed in 1947 had broken away (Koenig *et al.*, 1952, pp. 76–7).

From the present gradual wastage deduced from surface observations, it is concluded that only a slight amelioration of climate would be extremely destructive to the ice shelf. For example, continual mild seasons, like that of 1954, would cause the whole of the present mass of the ice shelf to melt in about 80 years. Such an eventuality does not take into account 'rejuvenation' of the ice shelf by freezing of sea water of very low salinity to the undersurface, which, as already stated, can take place to a depth of at least 20 feet. It seems most improbable, however, that an ice shelf could have persisted through the climate of the 'postglacial optimum', 4,000 to 6,000 years ago, and it is perhaps unlikely to have existed even as recently as 500 B.C., when the climate was apparently still slightly warmer than that of today. Moreover, the ice shelf could not have existed when driftwood was deposited near present sea level on the "mainland" shore opposite Ward Hunt Island. This discovery in turn suggests a relatively recent age. The dating of this driftwood by the Carbon 14 method is now being undertaken by J. L. Kulp[1] of the Lamont Geological Observatory, Columbia University, and, if successful, will give a definite maximum age for the ice shelf.

The possibility that land glaciers moving seaward down the fiords coalesced along the peripheral parts of the coast to form the ice shelf is discounted by the writer, who believes that the present ice shelf is and always has been essentially a static floating sheet which grew *in situ*.[2] Previous ice shelves, of dynamic character and greater extent, may have existed along this coast in earlier, more intensely glacial times. The present ice shelf has been affected by the glaciers which move down into the fiords to the extent that, in some places near the fiord sides, they have superposed themselves on the ice shelf,

[1]Under Contract AF. 19 (604)-1063 between Columbia University and U.S. Air Force Cambridge Research Center.

[2]*See also* Debenham, F. 1954. "The ice islands of the Arctic: a hypothesis". *Geogr. Rev.* Vol. 44, pp. 495–507.

Fig. 16. The large glacier 15 miles south of Alert Point, which has advanced across a marine terrace at an elevation of about 200 to 250 feet. 29 May 1954.

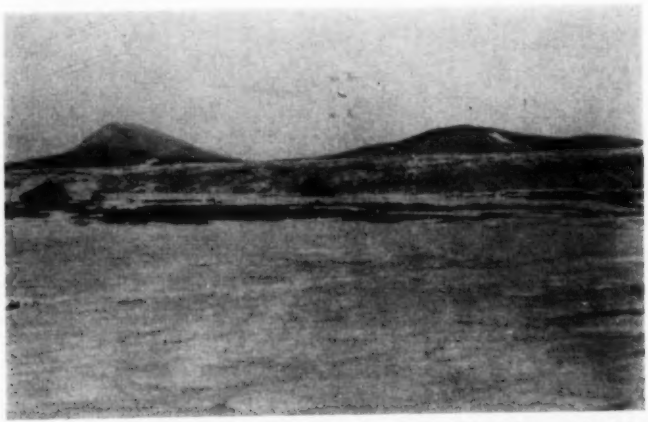

Fig. 17. Boulders near the edge of the ice shelf. Ward Hunt Island in background. 30 July 1954.

Fig. 18. Wide, steep-sided drainage channel on the ice shelf in the thaw season. Looking southeast to Disraeli Bay. 15 August 1954.

depositing moraines. By pressure against the shelf the glaciers have also imposed strain patterns, reflected in the disposition of the surface ridges and the drainage of the shelf. During the build-up of the ice shelf extensive developments of snowdrift ice formed in the lee of the fiord walls, and merged with the shelf. The snowdrift ice provided ramps down which meltwater streams carried the finer rock debris from the frost-shattered cliffs to the shelf; the boulders of medium or large size, as found on the edge of the shelf in Disraeli and M'Clintock bays, slid down these ramps from the cliffs above (Fig. 17). It also seems likely that the "ice rises", which cover some of the capes on the north coast of Ellesmere Island, developed at the same time as the ice shelf. It is thought that they may post-date raised beaches at the 15-foot level. Their present surface truncates depositional layers visible in vertical faces, usually on the east side of the "ice rise", indicating present wasting.

The considerable depth of water found beneath the ice shelf, rather than the relatively shoal water which had previously been expected, makes its present hold on the coast seem precarious. Some indication was found a few miles northeast of Cape Discovery of large cracks, which may mark the line of break-off of future ice islands. Similar cracks are visible in air photographs of Markham, M'Clintock, and Ayles bays.

The parallelism of the ice-shelf rolls to the coastline (Fig. 7) is most easily explained by forces acting from the sea, but the regularity of their spacing still remains an enigma, although it must be related to the thickness of the ice and to the depth of the water beneath. There is no doubt that the roll system, once started, will be perpetuated by the annual drainage (Fig. 18). An air photograph of ice in Hare Fiord, showing fractures, presumably associated with tidal action, spaced in a semi-regular manner, suggests a way in which a system of rolls might start. More or less regularly spaced "hedges" of pressure ice, separated by areas of smooth sea ice, in Yelverton Bay, also suggest a somewhat similar origin.[1]

Observations on land glaciers in northern Ellesmere Island have shown that there has been no marked recession in the last few decades. Vegetation right up to the high, cliffed fronts of piedmont glaciers coming down from the United States Range indicates that the glaciers are probably advancing. In 1953 a cairn was built near Cape Aldrich at a measured distance from the 80-foot ice-cliff, which parallels the shore for several hundred yards at the 200-foot level. Measurements in 1954 showed that the ice cliff had moved forward a distance of 20 feet. It is interesting to note that from Aldrich's sketch this cliff appears to have stood in roughly its present position in 1876 (*Parliamentary Paper*, 1877, *facing* p. 197).

The large glacier, which descends to the shore in a great icefall 15 miles due south of Alert Point, has advanced across a well-defined marine terrace at a height of 200 to 250 feet (Fig. 16). The appearance of the terminal moraines near the shore suggests lateral retreat of the glacier of not more

[1]We do not know what the response of a floating ice sheet is to tide and swell acting beneath it. The physicist may be able to provide the answer to this question, which would seem fundamental to an understanding of the rolls.

Fig. 17. Boulders near the edge of the ice shelf. Ward Hunt Island in background. 30 July 1954.

Fig. 18. Wide, steep-sided drainage channel on the ice shelf in the thaw season. Looking southeast to Disraeli Bay. 15 August 1954.

than 200 yards in recent decades. On the "mainland", to a height of 200 feet above the shore south of Ward Hunt Island, large heaps of talus and morainic material suggest that small snowdrift or corrie glaciers descended towards the shore in the not distant past. In Peary Land (north Greenland) Troelsen has correlated a glacial advance with the strand line at the 65-metre (213-foot) level (1952a, pp. 219–20), and in western Ellesmere Island he has reported a relatively late advance of the glaciers over the highest marine beach at about 465 feet (Troelsen, 1952b, p. 209). On the other hand Christie has reported undisturbed marine deposits with bivalve shells intact at a height of about 200 feet above sea level near the ice cliff of a small glacier above the shore of M'Clintock Bay. Furthermore the raised beaches on Ward Hunt Island up to a height of at least 125 feet above sea level have not been disturbed by glacial action. Kulp has used the Carbon 14 method to find the age of shells collected in 1954 from the latter beaches, and has arrived at a figure of 6,500 to 7,000 years (personal communication).

Tentative conclusions are that the glaciers in northern Ellesmere Island have not advanced greatly from their present positions since the formation of the marine beaches at the 200-foot level, and that recent minor extensions of land ice cover may have been contemporaneous with the development of the ice shelf. However, there is evidence of much more extensive glacierization in the more distant past in the Ward Hunt Island region. For example, an erratic piece of micro-granite, which can only have come from the "mainland", was found on Ward Hunt Island at a height of 1,100 feet (by aneroid). On the "mainland" glacial striae are very well-developed on an exposed rock ridge at a height of 2,500 feet, 5 miles southwest of the entrance to Disraeli Bay, in an area where now there are only a few rather inactive corrie glaciers. The more extensive glacierization must be presumed to predate the highest of the marine beaches so far found, namely at 300 feet.

Few data are available on the regime of the interior Highland Ice. In July 1953 the ice cap of the eastern part of the United States Range was visited, and the firn-line was found to be about 3,400 feet above sea level. At a height of about 5,000 feet density determinations showed that the surface accumulation for 1952–3 up to mid-summer was equivalent to about 7.5 inches of water, and that the net accumulation for 1951–2 was equivalent to about 6.3 inches of water. It is probable that the Highland Ice is in a state of near balance at the present time (Hattersley-Smith, in press).

The expeditions of 1953 and 1954 were concerned primarily with the ice shelf. A well-equipped expedition to the interior of northern Ellesmere Island is needed to fill an important gap in the glaciological knowledge of the north.

Geophysical and Oceanographic Studies. By A. P. Crary*

The U.S. Air Force Cambridge Research Center was mainly interested in possible correlations of the ice island T3 with the ice shelf, and the collection of geophysical data to increase our knowledge of the past and future of ice

*U.S. Air Force Cambridge Research Center.

islands. The general geophysical activities during the five months of the 1954 expedition are given below.

Survey: A line survey north and south across the width of the ice shelf a few miles west of Ward Hunt Island was made in three stages: distances were chained between the ridge tops; a levelling survey of elevations was made of all ridges between land and sea level, and a vertical angle stadia survey was made of the elevation differences between troughs and ridges using a one-minute Keuffel and Esser engineering transit. The total width of the shelf at the survey line was 11.9 miles, with the ridge and trough system rather poorly developed in the last mile or so near the seaward edge. There were about 75 well developed ridge systems which had an average wave length of approximately 760 feet. The ridges rose to about 24 feet above sea level near the land and, excluding the part near the seaward edge of the shelf, the differences in height between ridge and trough averaged about 7 feet.

A base triangle of about 2,500 feet on a side was used to locate the transit position at the main campsite on the shelf with reference to the neighbouring parts of Ward Hunt Island and near shore hills of the mainland. From this transit position 8 sun-lines were taken for approximate position, and elevation angles were measured on about 40 peaks visible along the northern shore of Ellesmere Island.

Using the transit compass and true azimuths, about 50 values of magnetic declination were obtained. Most of these were located along the north–south survey line across the ice shelf. A declination anomaly of about 10 degrees was found a few miles northwest of Ward Hunt Island, and a few additional observations were made there for detail.

Oceanography: During the period June 15 to 30 Hattersley-Smith and I travelled by dog team along the outer edge of the ice shelf between M'Clintock and Markham bays, a total distance of approximately 60 miles, to collect oceanographic data. Nineteen stations were occupied at fairly regular intervals, taking advantage of open water formed by the active sea ice, which, for the most part, was fairly close to the edge of the shelf. At two of the stations, off the northwest edge, no bottom was reached with the 300 metres of hydrographic cable available. Minimum depths of 60 metres were obtained at three separate points along the area studied. The sea east of Ward Hunt Island was in general around 100 metres deep up to the entrance to Markham Bay, where a sounding of 285 metres was taken. A total of 14 bottom samples, up to about 9 inches in length, was made with a Phleger sampler. Lithological and micropaleontological examinations of these cores are being carried out by D. B. Ericson at the Lamont Geological Observatory, Columbia University. Observations of ocean temperatures and collection of samples for salinity determinations were made at three stations 20 to 25 miles apart. At the centre station, off-shore from Ward Hunt Island, these observations were repeated at three intervals during the summer, with special attention being given to shallower depths. On September 17 and 18, Christie and I made a sledge trip into Disraeli Bay. Conditions prevented us travelling as far into

the bay as had been planned, but a hydrographic station was made about 10 miles south of the bay entrance. No bottom was obtained with the 300 metres of wire at hand.

In general we found that ocean temperatures were slightly higher than those obtained from T3, well out in the Arctic Ocean. It is hoped that these temperatures and salinities and their changes during the summer months will provide the necessary background for study of past and present accretion on, or wasting off, the bottom of the shelf by the water draining from the land and the shelf surface.

The oceanographic equipment: Nansen bottles, reversing thermometers, and Phleger sampler were loaned by the Woods Hole Oceanographic Institution, where the analysis of the water samples will be carried out.

Seismic studies: It had been hoped that systematic seismic studies could be made of the depth of the water under the ice shelf. However, the seismic operations were not started until August and sledging was not possible until early in September, hence water depths were obtained only in limited areas. A total of twenty-eight seismic stations was occupied and at the majority of these good bottom reflections were received. Along the ridge, running west from the main campsite, a deep canyon was found with a maximum depth of about 850 metres. This is believed to be the Disraeli Bay channel which probably continues northwest to the corner of the shelf, where depths were greater than 300 metres. A velocity profile was made at one site over deep water, using variations of reflection time with distance, in order to make certain that the reflections were not from a sub-bottom horizon. Nearly all of the seismic records across this channel provide some information on the slopes of the bottom and on sub-bottom reflection data. Because of the limitations of the equipment used and the large amount of energy present in the surface Rayleigh wave, it was difficult to obtain depth data when the combined thickness of the ice shelf and the water below was less than about 250 feet. Some shallow depths were taken by using a seismic arrangement that would allow the reflected energy to appear on the record before the surface Rayleigh wave.

A few records were made to find the thickness of the ice shelf itself. At two sites use was made of the vertically polarized transverse wave set up by large explosions. Reflections from the ice–water interface were also obtained in some cases, using the horizontally polarized transverse wave set up locally by mechanical means. In general, the thicknesses obtained, up to 150 feet, confirmed depths as calculated from ice surface elevations above sea level.

During the latter part of the summer, air temperatures dropped considerably and thermal contraction caused much cracking near the surface of the ice. At times the cracking was so frequent as to interfere with the seismic recordings; we were also troubled by the series of tremors "triggered off" when large explosive charges were fired, which obscured recordings of later phases. Advantage was, however, taken of these tremors, and during periods of their maximum frequency several recordings were made with three-component detector units. As they resembled miniature earthquakes, they should give considerable information on the character of the ice. Recordings

Fig. 19. Tide-crack system near the south side of the Ward Hunt Island "ice rise". 15 August 1954.

were made both on the ice shelf and on the ice field immediately west of Ward Hunt Island.

During the course of the seismic studies, a multiple pulse was obtained when shooting detonators in water-filled cylindrical holes. This multiple pulse has been observed in water but, as far as is known, has not been noted before in cylindrical holes. Variation of the pulse time with diameter of the hole was studied. This modification of the pulse time is possibly a function of the elastic constants of the ice and may prove useful in that regard.

Tide-crack physics: Proximity to Ward Hunt Island made possible a limited number of tidal motion studies in the stress zone between the floating ice shelf and the anchored "ice rise". This zone is characterized by a series of discontinuous shallow surface cracks. The elevations and extents of these tidal cracks were surveyed over a length of about 5 miles. The hinging action of the cracks was recorded on a rotary drum over a total of about 40 days and bubble levels, accurate to 30 seconds and to 1 minute, were also located across this tidal zone and read visually.

An interesting feature of the Ward Hunt tide crack system was the high elevation it attained in limited areas on the south side of the "ice rise" and directly opposite on the north side. This is believed to be a deep channel now filled with ice. Studies were also made of the old tide cracks which were exposed during the maximum melting (Fig. 19). Some data were obtained on the location and elevation of these old cracks, which were more numerous on the present "ice rise" than on the present ice shelf. They may reflect to some extent past changes in sea level and ice coverage.

A limited survey was made along the edge of the "ice rise" on the Ellesmere shore southwest of Ward Hunt Island. This "ice rise" is immediately south of the shelf proper and separated from it by a 300-foot moat of thin level ice where the drainage from land seems to have prevented build-up into an ice shelf. Measurements, taken at various places where the tide crack or the thin ice had been eroded through, showed an apparent correlation between the elevation of the active tide crack and the depth of water. Tidal recordings were also made in the waters near Ward Hunt Island and in M'Clintock Bay by Christie.

Ice temperature: Thermocouples were located in two holes on the ice shelf which were drilled for glaciological studies. The first of these was on the ridge at the main campsite and was drilled to about 80 feet. Salt water penetration in the bottom of this hole prevented the use of thermocouples below 70 feet, and undoubtedly influenced the temperatures somewhat at that level. A total of 10 thermocouples was located in this hole and read about once a week from early May to late September. The winter cold wave only penetrated through about the top 40 feet, below which the temperature remained at approximately -12°C. A comparison of approximate temperatures obtained during drilling in this hole, with those in the second hole in an adjoining trough, showed a difference of about 7°C to depths of 35 feet, where the trough hole was abandoned. The higher trough temperatures are probably due to heat obtained from the freezing of the lake waters the previous fall. Thermocouples were also placed to a depth of 59 feet in a hole drilled on the top of the Ward Hunt "ice rise" in early September. At lower levels the temperatures here were nearly constant at about -17°C.

Tritium dating: About 17 gallons of meltwater from the surface of the "ice rise" near Ward Hunt Island have been sent to J. L. Kulp for dating by the tritium method.

Meteorological data: Weather observations were made twice daily, near local noon and local midnight, during our entire stay. Except during short periods at the edge of the ice shelf, all observations were taken at the main camp. The following were recorded: air temperature, surface pressure, sky condition, visibility, cloud cover, and the direction and strength of the wind. During the period April 24 to September 26, minimum temperatures of -10°F and -3°F were recorded in early May and late September respectively, and a maximum of 42°F occurred in late July. The winds were remarkably constant in direction, mainly east or west, with all the heavy storms coming from the west.

Aerobiological collection: A total of 59 sets of treated slides were exposed in a continuous series between May and September for the collection of airborne pollen. These slides are being examined by N. Polunin of the Osborn Botanical Laboratory at Yale University.

Willow collection: Approximately 50 willows (*Salix arctica*) were collected in a limited area on the western slope of Ward Hunt Island for dendrochronological studies. It is expected they will extend back to 50 years or more; correlations will be attempted with willows found on ice island, T3.

Communications: Radio communication equipment consisted of a Harvey-Wells Bandmaster transmitter and a service receiver, R-100/URR. Both units were capable of operation on either 110 volts a.c. or d.c. A PE214 power unit delivering 300 watts was used as the a.c. source and for charging the wet batteries.

Frequencies used primarily were 3760 kc. for contacts with Alert Weather Station, and either 3452.5 kc. or 4220 kc. for contact with Thule Air Base and with aircraft. A total of 45 contacts was made with Alert, and through the cooperation of the station 38 official and 83 personal messages were handled.

Geological Observations, 1954.* By R. L. Christie†

The geology of the north coast of Ellesmere Island was essentially unknown, except for information brought back by H. W. Feilden of the British Arctic expedition of 1875–6 and by Admiral Peary in 1906, until 1953 when the geology from Alert westwards to Cape Columbia was studied by R. G. Blackadar (Blackadar, 1954; *Arctic*, 1954). In 1954 the coastal survey was continued to Lands Lokk.

The geological history is complex; formations of several ages and of various lithological types are found, and there is evidence of several periods of tectonic activity. The general geology appears to be as follows: an extensive gneiss and schist terrain of unknown age has been intruded by coarse-grained igneous rocks; extensive highly folded volcanic flow, tuff, and greywacke formations of early Paleozoic age or older occur, and presumably overlie the gneiss and schist; the volcanic sedimentary formations appear to be overlain by a moderately to severely folded early Paleozoic slate, sandstone, and limestone formation, and by fossiliferous, moderately folded, late Paleozoic limestone; dykes of fine-grained igneous rock cut all these formations; a small amount of poorly consolidated mudstone and sandstone of probably late Mesozoic or Tertiary age rests upon the eroded schists. Inland, stratified rocks are widespread, but they have not been correlated with certainty with the formations found at the coast.

The larger part of Ellesmere Island is within the Innuitian geological province.[1] Speculation has been made that northern Ellesmere Island is part of a eugeosyncline and is the core of the Innuitian orogenic system. The occurrence of volcanic and greywacke rocks suggests that a eugeosynclinal axis lay nearby in the past; they are possibly equivalent in age and orogenic history to early Paleozoic miogeosynclinal rocks of the eastern and northeastern coasts of the island. The existence of intense folding and intrusions of granitic, basic, and ultrabasic rocks support the hypothesis that the region is the core of an orogenic system. Metamorphic rocks of high grade indicate a long history of tectonic activity.

*Published by permission of the Deputy Minister, Department of Mines and Technical Surveys, Ottawa, Canada.

†Geologist, Geological Survey of Canada.

[1]First used in 1954 by Y. O. Fortier (1955) to describe the mountain system extending from the Beaufort Sea across the Queen Elizabeth Islands to Greenland.

The rocks between Cape Columbia and Lands Lokk

As described and named by R. G. Blackadar (1954), the Cape Columbia group, which consists mainly of biotite-feldspar gneiss, occurs at Cape Columbia. To the west, from Cape Nares to Ward Hunt Island, the gneiss formation is overlain, with angular unconformity, by moderately folded fossiliferous limestone of late Paleozoic age which appears to be equivalent to the Feilden group of northeastern Ellesmere Island. The unconformity is strikingly evident on the steep east face of Cape Nares (Fig. 3).

The mountains in the vicinity of Disraeli Bay are composed of a thick tightly folded formation including andesitic to basaltic flows, thick beds of breccias, tuffs, greywacke, and slate, and thin beds of quartzite and crystalline limestone. These rocks are slightly altered to chlorite-rock or "greenstone" in places; the low metamorphic grade contrasts with the more or less high-grade metamorphism of the Cape Columbia group. In the southern and western parts of M'Clintock Bay, the volcanic-sedimentary formation appears to be overlain by moderately to severely folded early Paleozoic slates, sandstones, and limestone. At the head of M'Clintock Bay a metamorphic rock, micaceous quartzite, occurs which is similar to parts of the ancient gneissic formation on Ward Hunt Island. The quartzite is overlain unconformably by almost flat-lying sandstones containing some non-marine fossils. The sandstone formation is very extensive; it appears to make up the high, glacier-hung mountains to the south and east, where, however, it is more or less distorted into open folds and some irregular overthrust folds.

On Cape Richards and Cape Fanshawe Martin there are outcrops of coarse-grained, plutonic rocks: granite and various norites and peridotites. These rocks intrude a quartzite that appears to be part of an extensive metamorphic terrain to the southwest.

Metamorphic rocks underlie the coast mountains from Ayles Bay to Alert Point. They are divisible into two lithological groups: medium- to coarse-grained gneiss and augen-gneiss, and micaceous quartzite, quartzite, mica-schist, and marble. The first group occurs on Cape Bicknor and Cape Evans. The second group underlies the region of Yelverton Bay and Alert Point, and appears to occur a few miles inland from Cape Bicknor and Cape Evans; the bedding in this group of sedimentary rocks is tightly folded, but little consistency in attitude is evident.

A few square miles of Alert Point is underlain by a poorly consolidated mudstone-sandstone formation which has, at least locally, been very violently contorted. South of Alert Point, a stock of fresh-looking granite lies adjacent to, and probably cuts, the schists and gneisses.

Between Phillips Bay and Cape Bourne a greywacke formation occurs. Greywacke, greywacke-tuff, and argillaceous greywacke have been fairly tightly folded, and slaty cleavage has been developed. Bedding trends northeast and east.

Between Cape Bourne and the westernmost extremity of northern Ellesmere Island there is a group of strongly folded, variously altered, andesitic flow-rocks and minor argillaceous and tuffaceous sedimentary rocks. Locally,

the volcanic rocks have been intruded and hybridized by dioritic to aplitic igneous bodies. At Lands Lokk fossiliferous, late Paleozoic limestone appears to overlie the steep-dipping volcanic rocks and to dip gently to the southeast. The limestone formation also outcrops up a fiord east of Cape Bourne as an outlier or extension of the structure at Lands Lokk.

New Names

New place names have been suggested only where necessary for the satisfactory description of the coastline and of the limited inland region travelled by the expeditions of 1953 and 1954. The following names, which for the most part commemorate members of earlier expeditions who are not already commemorated in the region, have been submitted to the Board on Geographical Names for their approval:

Ben Creek: A small stream flowing into Disraeli Bay.
Bjare Strait: For Age Rose Bjare of the German Arctic expedition, 1930.
Borup Point: For George Borup of the Peary expedition, 1908–9.
Cape MacMillan: For D. B. MacMillan of the Peary expedition, 1908–9.
Hansen Point: For Comdr. Godfred Hansen, leader of the Third Thule expedition, 1919–20.
James Ross River: Flowing into James Ross Bay.
Krüger Island: For H. K. E. Krüger, leader of the German Arctic expedition, 1930.
Marvin Islands: For Ross G. Marvin of the Peary expedition, 1905–6, 1908–9.
Matt Henson Bay: For Mathew Henson of the Peary expedition, 1905–6, 1908–9.
Moss Bay: Near Point Moss.
Patterson River: Flowing into Patterson Bay.

Texts of records which have not been published in facsimile

On Crozier Island

H.M.S. "ALERT," at Winter Quarters
(Lat. 82° 27′ North. Long. 61° 22′ West.)

HMS Discovery in Latitude 81°4′N Long 65.08 West.

This Island was visited by a sledge party from Her Britannic Majesty's ship "Alert" – Monday April 17th 1876 – under the command of Lieutenants Aldrich & Giffard who are on their way exploring the Northern Coast of Grant Land.

Names of Members of the Party

Joseph Good	Lieut. Giffard
[1]	Thos. Stuckberry
Wm. Wood	Rupert[2] Symons
Hen. Mann	Geo. Cranstone
Adam Ayles	Wm. Ellard
Thos. Stubbs	Wm. Woolley
David Mitchell	Wm. Lorimer
	Wm. Gore

Another party under Commr. Markham & Lieut. Parr are forcing their way due North over the Ice.

April 18th 1876

Pelham Aldrich
Lieutenant, Royal Navy

[1]Record torn, presumably removing name of James Doidge.
[2]Given as "Robert" in *Parliamentary Paper* (1877).

At Cape Fanshawe Martin

H.M.S. "ALERT," at Winter Quarters
(Lat. 82. 27 North. Long. 61. 22 West.)

HMS "Discovery" Latitude 81. 41 N. Longitude 65. 8 W.

This Cairn was built by the "Challenger" sledge crew detached in an exploring position to the Westward from HMS "Alert" G. S. Nares Esq. Captain. No cairn has been built westward of this one, and this does *not* mark the farthest position attained by the party. The extreme position is shewn in the accompanying chart, as across three more bays and some 43 miles beyond this Cairn.
In addition to this sledge expedition a Northern Division under the command of Commander Markham is endeavouring to force its way Northward over the Ice – and HMS "Discovery" has parties away performing similar duties on the North shores of Greenland.
The "Challenger" is now 52 days from the ship & on the homeward journey.
Names of the Party.[1]
Joseph Good
Jas Doidge
Serjeant Major Wood
Thos Stubbs
Hy Mann
David Mitchell
Pelham Aldrich. Lieutenant in command of the party.

May 24th 1876.

At Cape Aldrich

3rd Thuleexpedition
Norges Depotexpedition til Kapt. Roald Amundsen
April 21 1920

In this cairn was found a record from Mr. McMillan of the Peary Club North-Polar-expedition 1908-09 dated Dec. 1908. It states that McMillan lived here for a months[2] to take tidal observa tions. The tidal iglo was situated South 8° East 77 feet 9 inches from the iron pipe, the top of which was 8.37 feet above Zero of the gauge.

The original Record was spoiled by the dogs during night, so I have had to make this brief statement.

Godfred Hansen
Comm. R.N.
Denmark

On Ward Hunt Island

Sunday, March 21, 1909.
To whom it may concern:
at the request of Commander R. E. Peary, who is now out on the Polar Sea at about lat 85, I am leaving this cache as a possible aid to some one landing near here by a westerly drift.

D. B. M[c]Millan
Assistant.

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[1]The name of Adam Ayles was obviously omitted by mistake. In *Parliamentary Paper* (1877, p. 216) it records that he built the cairn with Lieutenant Aldrich.

[2]The sense is not quite clear, but reference is made to MacMillan's occupation of the tidal igloo from 17 November to 13 December 1908 (Peary, 1910, pp. 157 and 305).

Message left by Aldrich on the chart at Cape Fanshawe Martin

This chart has been roughly sketched in under a variety
of circumstances on the outward Journey.
Fogs and bad weather have sometimes been experienced.
The Latitude of the North Cape is about 83.5 N.
and that of Cape Alert[1] will be about 82.20 N.
The Longitude may be considerably adrift as it is judged
merely from the estimated distances run by the sledges.

Pelham Aldrich
Lieutenant
HMS "Alert"

May 24th 1876
Her Majesty's Birthday

Records and Relics Recovered

Site	*Expedition*	*Year*	*Leader*	*Records and Relics*
In 1953				
12 miles south of Cape Sheridan	"British Arctic"	1875–6	Capt. Sir G. S. Nares, R.N.	Clothing and equipment from camp established by Lieut. G. A Giffard and Sub-Lieut. C. I. M. Conybeare, R.N., on 7 July 1876.
Crozier Island	"British Arctic"	1875–6	Capt. Sir G. S. Nares, R.N.	Record signed by Lieut. Pelham Aldrich, R.N., and dated 18 April 1876.
Eastern summit of Cooper Key Mt., Cape Columbia	"Peary Arctic Club"	1905–6	Comdr. R. E. Peary, U.S.N.	Piece of United States flag, and record signed by R. E. Peary and dated 8 June 1906.
Cape Sheridan	"Peary Arctic Club"	1908–9	Comdr. R. E. Peary, U.S.N.	Man pemmican by Armour Co., Chicago.
Cape Aldrich	"Third Thule" (in support of Capt. Roald Amundsen's North Polar drift in the *Maud*)	1919–20	Comdr. Godfred Hansen, R.Dan.N.	Sledge-rations by Beauvais of Copenhagen; shotgun-rifle and ammunition; primus stove; kerosene; mail and dispatches for Capt. Roald Amundsen; 2 pairs of snow-goggles.
In 1954				
Cape Fanshawe Martin	"British Arctic"	1875–6	Capt. Sir G. S. Nares, R.N.	Chart and record signed by Lieut. Pelham Aldrich, R.N., and dated 24 May 1876.
Cape Colgate	"Peary Arctic Club"	1905–6	Comdr. R. E. Peary, U.S.N.	Record signed by R. E. Peary and dated 5 July 1906.
Ward Hunt Island (north side)	"Peary Arctic Club"	1908–9	Comdr. R. E. Peary, U.S.N.	Record signed by D. B. MacMillan and dated 21 March 1909; komatik; lamp-stove; 6 cans of stove fuel; canister of tea; 3 cans of milk.
Ice shelf 3 miles south of main camp	"Peary Arctic Club"	1908–9	Comdr. R. E. Peary, U.S.N.	Tins etc., at old campsite.
3 miles south of Cape Aldrich	"Third Thule"	1919–20	Comdr. Godfred Hansen, R.Dan.N.	Record signed by Godfred Hansen, dated 21 April 1920, and left in MacMillan's tide gauge.
4 miles west of Cape Colgate	"German Arctic"	1930	Dr. H. K. E. Krüger	Record signed by H.K.E. Krüger and dated 22 April 1930.

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[1]Alert Point on Fig. 2.

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THE 1953 LEMMING EMIGRATION AT POINT BARROW, ALASKA

Daniel Q. Thompson*

DURING the summers of 1950 to 1954 the writer studied the ecology of the brown lemming, *Lemmus trimucronatus* (Richardson), at the Arctic Research Laboratory, Point Barrow, Alaska.[1] Field work was begun one year after the mass die-off of 1949, described by Rausch (1950). The first indication of recovery in the lemming population from the 1949 die-off was evident in August 1951, when a phase of proliferation began which continued into 1952 and 1953. Early in June 1953 the onset of a phase of declining lemming numbers was marked by a mass movement that attracted brief but widespread notice. The present paper describes certain biological characteristics of this interesting population phenomenon.

When I arrived at Barrow in mid-May 1953, the tundra was covered with snow about 11 inches deep. Air temperatures varied from 15° to 19°F and essentially winter conditions prevailed until the end of May. Several hundred snap-traps were set under the snow in May to obtain lemmings. Signs of lemmings, clippings and droppings, were found on almost every square foot of the tundra. Most of the snow mantle had been undercut by a network of ground-surface tunnels made by lemmings looking for food (Fig. 1). Later measurements determined that lemmings had clipped over 99 per cent of the standing vegetation.

On May 31 air temperatures rose to 35°F and the snow mantle began to melt rapidly. Prior to this thaw, individual lemmings had made very brief appearances only on the surface of the snow. During the first days of June, however, lemmings began to make prolonged excursions over the snow surface. On June 3 wandering lemmings appeared in the broad gravel streets of Barrow base camp, which stretches for one-half mile along the shore of the Arctic Ocean. Their appearance aroused much interest among the oil exploration workers, who had never seen lemmings behaving like this before. Lemming activity on the surface of the snow increased the next day, June 4, and it was apparent that there was mass unrest in the population. Lemmings could be seen scurrying about on the snow surface in all habitats; they continued to appear in the camp streets, and many wandered beyond the camp on to the arctic ice pack that was grounded along the shoreline.

In order to follow changes in the density of wandering lemmings, a daily search of the Barrow camp, an 80-acre area, was begun on June 6. Each day

*Department of Zoology, University of Missouri, Columbia, Missouri.

[1]This study was supported by the U.S. Office of Naval Research and the Arctic Institute of North America.

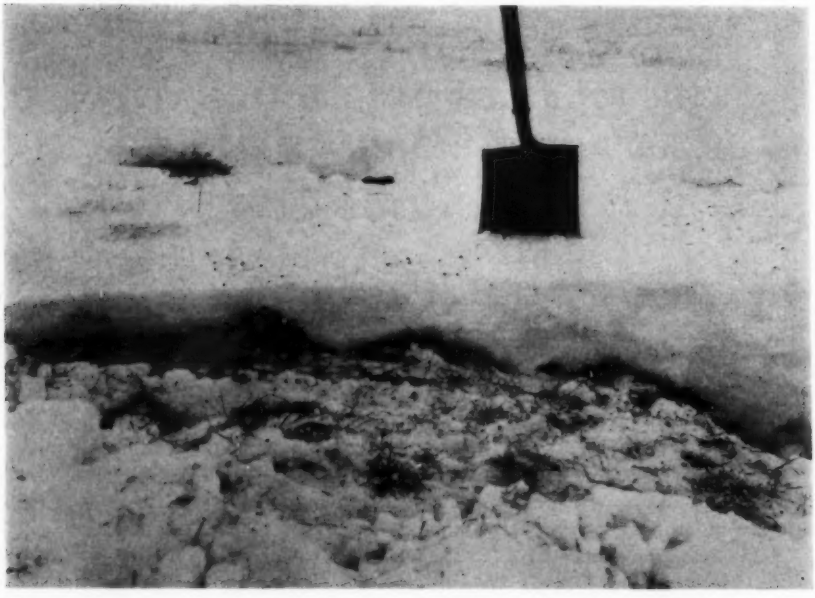

Fig. 1. Snow trench cut across the edge of a polygon showing clipping of all winter forage by brown lemmings. Erect stems in background are dead material which has not been clipped. 19 May 1953.

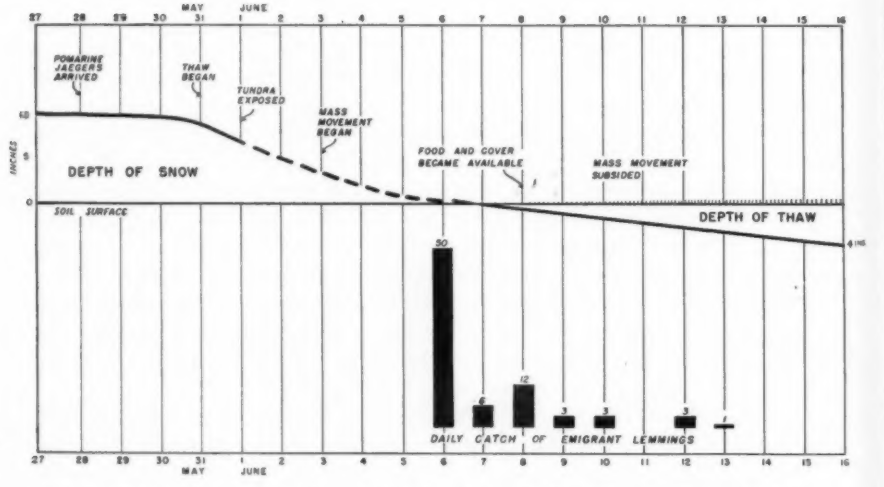

Fig. 2. Schematic representation of the phenology of the 1953 mass dispersal of brown lemmings at Point Barrow.

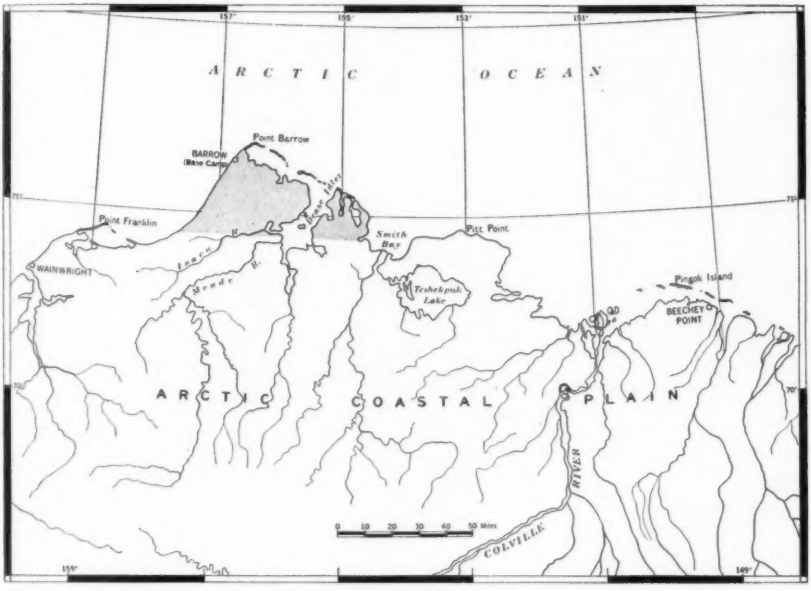

Fig. 3. Area of abundance of brown lemmings in 1953 shown by stipple.

all lemmings sighted throughout the camp were promptly pursued and, with few exceptions, captured. Each evening a careful search was made for lemmings which had sought cover under fuel drums, heavy equipment, and construction materials in storage on the dry, gravel-surfaced camp area. Since an unknown number of lemmings doubtless moved through the camp without being detected, the results only indicate the approximate magnitude of emigration from the adjacent tundra, but observations on the rate of movement of individual lemmings in the camp area suggest that at least two-thirds of those entering the area were captured (Fig. 2). The taking of 50 lemmings on June 6 does not indicate a great influx on that particular day; rather, this striking number represents an accumulation of lemmings throughout the camp area from June 3 to June 6, when the first special effort was made to capture them. The greater part of the movement occurred over a period of five days, June 4 to June 8, during which 73 lemmings were taken on the 80-acre area, an average of nearly one lemming per acre. The average daily catch was one per 5 acres. Wandering lemmings were seen daily in the camp streets until June 13, but by then the period of maximum movement had passed. A few emigrants entered camp in the last two weeks of June, and the last lemming was captured in camp on July 1.

It should be emphasized that the mass movement did not resemble the spectacular migrations reported from Scandinavia (Elton, 1942, p. 213). The lemmings appeared to be engaged in a haphazard dispersal or shuffle, in which

Fig. 4. Wandering lemming which had taken up temporary residence under a pile of construction material in the camp area. The erect pelage and rounded body form are typical of lemmings suffering from malnutrition and exposure. 5 June 1953.

only a small and peripheral part of the population pushed on to the ocean ice. On several occasions, I reconnoitred the ice hoping to find a concentration of lemmings that would make mass collecting feasible, but densities of moving animals were too low to encourage efforts to obtain an adequate sample for population analysis.

Reports from field observers indicated that the area of movement was confined to the northern tip of the coastal plain. Wandering lemmings were reported as far as 10 miles out on the ocean ice on a front extending approximately 30 miles southwest and southeast along the coast from Point Barrow. I made a reconnaissance in July and found from a range survey that the area in which lemmings had reached a peak abundance extended 30 miles inland from Point Barrow to the vicinity of the Inaru River (Fig. 3).

Behaviour of emigrant lemmings

From June 3 to 8, in nine periods of 15 to 20 minutes each throughout the day, individual lemmings moving on the surface of the snow were watched to determine whether their travel was oriented. In every instance the pattern of movement was erratic; some lemmings moved in large circles, some moved in all directions, and others retreated to the point of origin.

Fifteen of the wandering lemmings were captured and caged at the Arctic Research Laboratory for observation. These captives were no more aggressive than dozens of others studied in the previous three years; indeed, they were socially tolerant to the extent of huddling together for warmth.

The lemmings that wandered into the camp area showed a normal tendency to occupy a home range. They took up temporary residence under a pile of lumber (Fig. 4) or other protective cover and could be seen near this cover for several days. One such transient established himself under a stockpile of steel pipe, eluding my attempts to capture him for four days. During this period his only apparent food was an old orange peel and the carcass of another wanderer. Cannibalism was common among wandering lemmings in the sense that live ones fed on the carcasses of those killed by camp vehicles.

Comparison of emigrant and tundra[1] lemmings

To compare the density of lemmings in the camp area with that on the tundra, animals on a series of 60 census plots were counted during the period of mass movement. In the most representative type of tundra habitat, an average of 42 lemmings per acre was captured. This contrasts sharply with the total catch of one lemming per acre in the camp area, indicating that the wanderers represented but a small fraction of the tundra population.

The following table shows the comparison between some characteristics of the wandering and the tundra animals. Approximately 4 out of every 5 wandering lemmings captured in the camp or on the ocean ice were males

Table 1. Comparison of wandering lemmings with those captured at random on the tundra. Body, adrenal, and testis weights are reduced to a body length of 100 mm.

	Wandering lemmings	*Sample*	*Tundra lemmings*	*Sample*
Sex ratio	374 ♂♂/100 ♀♀	90	112 ♂♂/100 ♀♀	458
Age ratio	10 juv./100 ad.	90	18 juv./100 ad.	458
Body weight (males only)	43 gm./100 mm.	36	49 gm./100 mm.	43
Adrenal weight (males only)	9.3 mg./100 mm.	15	8.6 mg./100 mm.	9
Greatest diam. of uterine horn	1.2 mm.	12	2.0 mm.	35
Testis weight	212 mg./100 mm.	24	253 mg./100 mm.	31

whereas the sex ratio was approximately one to one on the tundra. It seems that there were relatively fewer juveniles[2] among the emigrant population; however, this difference is not significant when tested by the chi-square method. The animals in which the body weight, adrenal weight, diameter of uterine horn, and testis weight were measured were taken at random from the same size classes, and were captured on the same dates. Comparison of

[1]The "tundra" lemmings were captured one mile inland. Dispersal and changes of habitat were probably occurring when the sample was taken.

[2]Lemmings below 120 mm. in various stages of juvenile pelage are called juveniles; lemmings measuring 120 mm. or more are designated as adults.

body-weight with body-length indicates that the wanderers weighed approximately 20 per cent less than lemmings on the tundra. Empty alimentary tracts probably accounted for much of this difference, for the emigrants carried a normal amount of subcutaneous fat. Heavier adrenal gland weights are indicated for wandering lemmings, but the difference is not significant.[1] The summer reproductive season had begun at the time of the mass dispersal. Pregnancies were not yet visible in the females; therefore the diameter of the uterine horn was used as an indicator of reproductive activity. These measurements show that the uterine horn diameters of emigrant females were smaller than those of females of the same mean total length captured on the tundra over the same span of days. Likewise, the testis weights of emigrant males were considerably less than those of comparable tundra males. The differences between body weight, testis weight, and uterine horn size of the wandering and tundra lemmings were so great that they could be expected to differ this much by chance alone less than two times out of a hundred;[2] they can therefore be considered real differences.

Causes of emigration

Changes in available food and cover were the only factors that could be correlated with the beginning and end of mass unrest in the lemming population. As the snow mantle melted and the winter tunnels collapsed, the lemmings were forced to venture on to the scattered bare patches of tundra (Fig. 5), and were pitilessly exposed to weather and to avian predators; the newly uncovered tundra was still frozen, preventing the lemmings from using old burrows or forming new tunnels in the surface vegetation. By June 10 only ten per cent of the snow cover remained; the rest of the tundra had thawed sufficiently to allow the lemmings to use old burrows which were free of water, and to make new tunnels in the moss carpet which underlies the standing vegetation (Fig. 6). In addition more forage was available as the moss carpet thawed, and the lemmings were able to dig out the crowns of grasses and sedges (chiefly *Dupontia*, *Eriophorum*, and *Carex* spp.) which had previously been frozen in the sod. The growihg season was also underway and each day added a millimetre of new growth to the grasses and sedges. By June 13 the surface thaw averaged three inches on hummocks and one inch in polygonal depressions, and the height of new green growth averaged five millimetres in the depressions. The lemming movement had subsided.

As a means for relieving population pressure, the mass dispersal would seem to have had only a minor effect. Mortality from predators was a far more potent mechanism of population control. This was emphasized by the fact that an average of 11 dead lemmings per acre was found in 30 sample plots on the tundra.

[1] $t=.0349$; $P=>.90$.

[2] Body weight, $t=3.104$, $P=<.01$; testis weight, $t=2.426$, $P=<.02$; uterine horn size, $t=3.125$, $P=<.01$.

Fig. 5. Appearance of coastal tundra during the peak of the mass lemming movement of 1953. 5 June 1953.

Fig. 6. Surface tunnels thrown up in moss carpet in trough of polygon. 26 August 1953.

Frequency of emigration

Clarke (1940, p. 69) and Elton (1942, p. 469) reviewed the records of the emigrations of collared (*Dicrostonyx*) and brown lemmings in the Canadian Arctic. More recently, Gavin (1945, pp. 229–30) reported an emigration of brown lemmings at the mouth of the Perry River in early May 1937. He noted that the movement continued for ten days and nights in an easterly direction, and estimated densities of one lemming per square yard. Gavin also refers to an earlier mass movement—southward—which he witnessed on King William Island in 1934; he considers this movement to be of a much lesser magnitude than that at Perry River in 1937. Clarke (1940, p. 69) and Elton (1942, p. 469) point out that although emigrations are associated with peaks in population, the number of emigrations are few in comparison to the records of peak abundance.

The situation seems to be much the same in the Alaskan Arctic. Brower (1942, p. 123) recalls a mass movement of great proportions at Point Barrow in late May 1888. He describes the tundra as being black with lemmings coming from the southeast and moving seaward on a 10-mile front; the main body took four days to pass the whaling station. Harmon Helmerick (J. W. Bee, personal communication) saw lemmings on the Arctic Ocean ice 10 miles north of Pingok Island (near Beechey Point) in April and May 1946. This is an interesting observation, since it coincides with the peak lemming year of 1946 at Point Barrow. Stuck (1920, p. 227), describing lemming movements in the Alaskan interior, writes of a mass of floating, dead, brown lemmings in the Yukon River about 10 miles from the Canadian boundary in 1918. Stuck's trail companion, Walter Howard, had seen a similar movement in earlier years.

On the Alaskan Arctic Slope the lemming is of no direct importance in the native economy and therefore receives little attention from the local Eskimo. Nevertheless, recollections of five reliable native observers, whom I interviewed, were in substantial agreement that mass movements, such as that of June 1953, have occurred slightly more often than once each decade. That is to say, Eskimo in middle age recalled having seen two or three such spring movements in the past two decades. One of these observers had lived inland for many years and remembered a movement of brown lemmings in autumn.

In comparison with the brown lemmings in arctic Alaska, the emigrations of the Norway lemming (*Lemmus lemmus*) in Scandinavia (Collett, 1895; Elton, 1942; Wildhagen, 1952) and Finnish Lapland (Pleske, 1884; Kalela, 1949) are much longer in duration, more frequent in occurrence, and involve greater densities of moving animals. The migrations of the Norway lemmings are also more uniformly oriented as to direction of travel and involve greater distances.

Several possible explanations can be found for these differences. First, there is great contrast in the topography of the two ranges. The lemming range in Norway is a high plateau which is intricately dissected by valleys and fiords. As Elton (1942, p. 216) and others suggest, any lemmings moving

over this terrain would soon be trapped in one of these valleys and funnelled into the fiords. The arctic coastal plain at Barrow, on the other hand, is a flat shelf which scarcely rises above sea level, and would have no appreciable effect in orienting the movements of a wandering animal population. Secondly, the habitats within the two lemming ranges are quite different. The Alaskan arctic coastal plain is a monotonous expanse of grass, sedge, and lichen; in contrast the northern European range is a patchwork of altitudinally zoned vegetation in which the subalpine zone is the preferred lemming range. Thirdly, innate differences in the behaviour of the two lemmings exist. For example, the Norway lemming is nocturnal (Collett, 1895), whereas the brown lemming at Point Barrow is active at all hours from June until September. This may be of no particular significance as regards the inclination to emigrate, but it does suggest rather sharp behaviour differences between the two species.

Kalela (1949) regarded the "migrations" of the lemmings in Finnish Lapland as a peripheral manifestation of a much greater internal shuffle within the major lemming range. At Point Barrow during the 1953 mass movement of lemmings, a relatively small fraction only of the tundra population actually wandered out on to the arctic ice pack. It seems that these peripheral movements may also indicate an extensive internal shuffle within the coastal area. Population pressure was relieved much less by the mass dispersal than by mortality from predators, and the exodus of emigrants dropped off sharply as the surface of the tundra thawed, making food and cover available. In general, mass movements of the brown lemming seem to be less intense and less frequent than those reported for the Norway lemming in northern Europe.

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NOTES ON CAPTIVE SEA OTTERS*

Charles M. Kirkpatrick[1], Donald E. Stullken[2], and Robert D. Jones, Jr.[3]

THE former range of the sea otter (*Enhydra lutris*) extended along the Pacific coast from lower California northward to the Aleutian Islands, and westward to the Komandorskiye Ostrova (Commander Islands), the Kamchatka coast, and the Kuril'skiye Ostrova (Kuril Islands). The species was nearly exterminated in North American waters around 1900 by fur-hunters. In 1911 total protection was given, at least on paper, to the depleted North American population and the establishment of the Aleutian Islands National Wildlife Refuge in 1913 added reality to the legal protection. With improved control through the administration of the refuge and the presence of armed forces in the islands, which has acted as a deterrent to international poachers, the otter population has made a marked recovery in certain areas, such as Amchitka Island. However, natural redistribution occurs slowly and there is inconclusive evidence of inter-island movement among the otters. Because of this inertia an early step in the management of sea otters will be the restocking of suitable parts of the former range with captured wild animals. The relative ease with which otters may be approached and taken in a large landing net on beaches and, at times, in the water suggested that this operation would be feasible.

Employees of the U.S. Fish and Wildlife Service, working with a considerable knowledge of the wild sea otter (Fisher, 1939; Murie, 1940; Jones, 1951a), therefore made repeated attempts, beginning in 1951, to maintain captured sea otters for the purpose of relocating them. Unfortunately, all otters taken during several winter seasons died within a few hours or days. Observations made on the dead and dying otters (Jones, 1949–53) suggested that mortality was due to a stress or shock reaction incident to capture, handling, and confinement. Accordingly, the U.S. Fish and Wildlife Service and the Purdue University Agricultural Experiment Station collaborated on a preliminary physiological investigation to determine the cause of mortality among captive sea otter on Amchitka Island in February and March 1954. These months were chosen because in late winter the otters are concentrated inshore and are easier to catch. During the investigation the research team made physiological

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[1]Associate Professor of Wildlife Management, Purdue University Agricultural Experiment Station.

[2]C.N.A.T.R.A. Staff, Naval Air Station, Pensacola, Florida.

[3]U.S. Fish and Wildlife Service, Cold Bay, Alaska.

Fig. 1. Adult male seal otter, weight 70 pounds, in holding tank. Note bristly appearance of lighter head fur, vibrissae, and short claws on upper side of fore paws.

observations on twenty-two otters, three of which survived and were placed temporarily in the Seattle Woodland Park Zoo before being transferred to the National Zoological Park, Washington, D.C., on 14 June 1954. This paper is based on the reactions of these three to captivity and handling up to the time they left Seattle, and of others held for shorter periods. Results of the physiological investigations will be reported elsewhere (Stullken and Kirkpatrick, 1955).

The research team met with disappointments and failures in trying to develop satisfactory methods for handling and feeding. The survival of three otters showed some degree of success, but their welfare was not jeopardized by experiments to determine the limits of their tolerance to various aspects of handling. Had we known about the success of the Russian work in the Komandorskiye Ostrova (Mal'kovich, 1937; 1938), we might have benefited from their experience in keeping confined otters in good health, particularly as regards the amount of food needed daily. Their Ostrov Mednyy (Copper Island) sea otter station established in the early 1930's is described by May (1943) and illustrated by Hrdlicka (1945, p. 396), both of whom visited the island in 1938. Results of the Russian work did not reach us until our expedition ended, but interesting similarities in observations, methods, and results are apparent.

The sea otter is at home in water, but on land its body is pendulous and poorly supported by the relatively short, muscular limbs. The total length of an adult is about four feet, and the females are generally smaller than the males. Among the animals we handled, four adult females ranged from 38½ to 50 pounds, and males, apparently older than yearlings, ranged from 30 to

82 pounds. Scheffer (1951) records a female of 43¼ pounds and a male of 76 pounds. Mal'kovich (1937) gives the weight of a captive male at 37.3 kg. (82 pounds).

The musteline head is flat and blunt, the eye small and dark, and the small external ear, fleshy, vascular, and naked, is twisted upon itself. A blunt, black nose pad separates stiff decurved vibrissae (Fig. 1). The fore paws are pad-like with no separation of the digits, although the terminal phalanges are movable and give great flexibility to the tips of the paws. The short and slightly curved claws are normally retracted on to the back of the paw but may be rotated forward to extend beyond the tip of the paw. The hind foot is a broad, flipper-like structure, fully webbed, each digit having a nail-like claw above and terminal callouses below. Unlike the fore paw, the hind foot is furred on both sides and all phalanges are mobile. In the following discussion the fore feet and hind feet will be referred to as paws and flippers respectively.

The body fur is dark, soft, and luxurious, with fine dense guard hairs and under fur, but the head fur has a bristled appearance. In some individuals the head and neck are a contrasting buff colour, and grizzling of guard-hair tips is common in older otters. The fur of the chest is usually worn shorter than that of the rest of the body. The skin is remarkably loose on the body, even about the head, and is not underlain with blubber as in other marine mammals. There is a capacious fold of skin on the chest extending from one arm-pit to the other, which the otter can manipulate to form a pouch for holding food; however it is not an enclosed structure like a marsupium (Fig. 2).

Captive otters and their environment

In previous years the sea otters captured at Amchitka were held in fresh-water ponds or in a tank about ten feet in diameter, containing sea water two feet deep and a small platform of rocks (Figs. 1 and 3). The longest time any otter survived in the tank was eleven days, most deaths occurring much sooner, usually preceded by the otter shrieking. Since the temperature of the water in the tank fell below that of the sea, it appeared that otters kept in the tank suffered from cold. This was supported by the observation that young otters

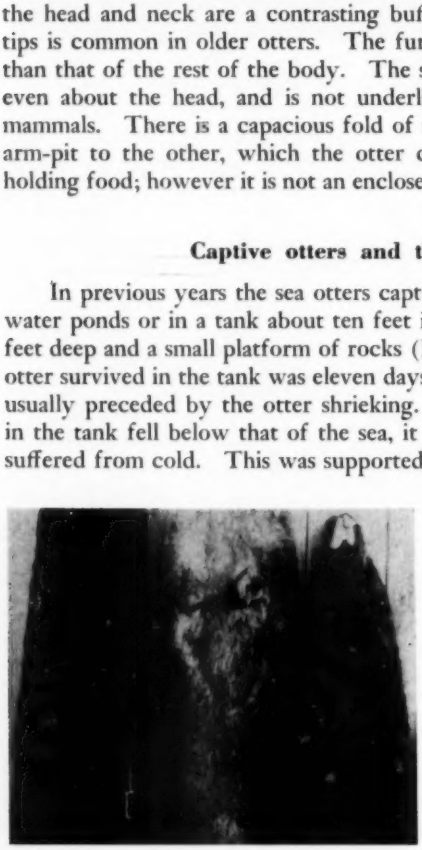

Fig. 2. Skins at centre and right show the outline of the loose skin and short fur of the chest pouch.

transferred from dry quarters to the tank for a cleansing bath began screaming almost at once.

In 1954, as it seemed that exposure to cold was one cause of mortality, we held some animals in a dry environment. Three of these otters survived two and a half months without water for swimming until they were temporarily transferred to the Seattle Woodland Park Zoo. When released there, in an enclosure with a freshwater pool four feet deep, the otters promptly entered the water and swam. However, during their first swim they began to shiver without coming out, so the pool was drained to help them regain the shore and dry themselves. The next day they swam, and again showed signs of cold but soon climbed out to dry. After about three days they used the water normally without getting cold. Presumably the water-repelling properties of their fur had recovered after being temporarily destroyed by keeping them dry and permitting their fur to become dirty. Our observations, as well as the Russian reports, show that water for swimming is desirable, if not necessary, for the welfare of captive sea otters. The temperature of the water is important, but the exact water temperatures that captive sea otters can tolerate are not known. The annual fluctuation of the sea temperature at Amchitka Island is from 38°F to 47°F. Water in the Seattle Zoo pool was about 50°F, and daytime air temperatures of 60° to 65°F caused no signs of distress.

The subjects for most of our observations were three young, probably yearling, otters: one female (Hortense) weighed 19¾ pounds when captured, one female (Aggie) weighed 24 pounds, and a male (Peter) weighed 25 pounds.

For eleven days after capture Hortense was kept as a pet in the heated house serving as laboratory and living quarters for five men; she had the run of the dry, bare floor during the day. At night she was confined in a cage containing grass. The cage consisted of a wooden frame 1½ x 2 x 4 feet covered with 1 x 1-inch welded wire fabric. Aggie and Peter were confined in similar cages during the early days of their captivity. They were never taken into a heated building, but were let loose in the "otter house" six days and one day after capture respectively. The "otter house" was a small, wooden warehouse, well ventilated and fairly well lighted by windows facing north and east. Neither walls nor windows completely prevented the penetration of the wind-driven rain, so that walls and floor were usually damp. Fresh, dried grass spread upon a layer of sawdust kept the otters from contact with the plank floor. The "otter house" provided an open space of about 15 x 20 feet and room for the cages which were supplied with grass bedding and raised several inches above the floor. At night the otters used the cages freely, irrespective of ownership.

The otters successfully maintained in captivity were fed four times daily at 0700–0730, 1100–1200, 1600–1700, and 2100–2300 hours. After the food requirement was determined, each otter consumed a total of six to seven pounds of fish per day, about one or one and a half fish per meal.

Little handling of the otters was necessary. Weights were taken by dropping a large sack over an animal, scooping it up, and then weighing the sack with the animal in it.

Sleeping: The normal sleeping position was on one side or supine, rarely prone. The head and neck were usually turned to one side, with the hind quarters curved or straight. The paws were held either rigid or relaxed, usually with the palms together beneath the chin or pressed tightly over the ears. In the latter position the muzzle was thrust into the pouch region. At other times the head rested upon the palm of one paw, and the other paw relaxed under the chin or extended outward or upward. The flippers usually were spread, sole down, with the tail straight back, but commonly one or both of them was turned nearly at right angles to the long axis of the body. Occasionally, when an otter lay prone, its flippers were flexed forward under the abdomen. When the otter was supine, an intermittent reflex raising and outward rotation of its flippers suggested sculling, like that which takes place when the otter floats asleep or awake in the water. (This reflex also occurred when the otters fed on their backs). Breathing movements occurring at a rate of about 12 per minute were accompanied by slight nostril dilation and twitching of the vibrissae. Otters sound asleep on a wooden floor were not awakened by gentle walking or normal conversation a few feet from them.

Preening: The otters preened regardless of the condition of their fur, but rubbing was intensified when the fur was wet. Fluffing the fur occurs both in and out of the water, and might be considered a nervous reaction because it appears to be an automatic function in both wild and captive otters (Fisher, 1939, p. 24; Jones, 1951b, p. 354).

Preening was carried out in any position. A supine animal might raise its head, thrust its nose into the fur of the chest or abdomen, and rub it rapidly from side to side, snorting and blowing. Simultaneously the paws rubbed sides, haunches, face, ears, or neck with rapid rotary, and to and fro motions. Folds of the lose body skin were repeatedly gathered and scrubbed vigorously between the paws. Paw movements were not always synchronized. Hortense was adept at rubbing her right elbow with her left paw while rubbing her face with the back of her right paw. With arms folded before the chest, the otter rubbed opposite forelegs or shoulders with both paws simultaneously or the backs of the opposite paws alternately. In this action the digits were frequently extended outward away from the palm. There seemed to be no part of the body the fore paws could not reach and rub. There was much snake-like wriggling on the straw accompanied by pushing of the flippers against the floor and ear rubbing while the otters were on their backs, sides, or bellies. In the cage the wire was used as a rubbing surface for head, neck, and sides. When the fur was wet, the head and neck were shaken vigorously, in many positions, occasionally accompanied by a flipper scratching the shoulder region. Vigorous shaking in a half-reclining position swung the paws away from the body centrifugally, and even rotated the whole body to some extent.

When permitted freedom of the "otter house", the otters sought the drier areas of straw for preening and sleeping, although warmer spots in direct sunlight were usually avoided. When reclining, the otters occasionally drew bunches of loose grass over themselves, rubbing the grass between the paws

and against the body; however, this was not kept up for long at a time. On days when the soiled, damp, and matted grass was replaced with clean, dry grass, the otters' interest in grass increased and they frequently climbed into the box containing fresh bedding. They apparently enjoyed handfuls of grass dropped directly upon them.

While in any position the otters moved their skin to and fro, mainly in the abdominal and lower back region and less about the shoulders. This action, also noted in wild sea otters (Fisher, 1939, p. 24), is apparently done by contraction of dermal muscles; it is not a rapid twitching like the flicking of a horse's skin, but a slower peristaltic-like wave easily followed by the eye. Its purpose may be to separate water-matted fur by raising the guard hairs, although the movement also occurred when the fur was dry or nearly so.

For a few hours after capture, especially when wet and nervous, the chest and, less commonly, the sides and haunches were vigorously slapped with the paws. This resulted in water spattering from the fur and paws, but it may have been a nervous reaction only since it was particularly marked immediately after capture. Depending upon conditions and size of the otter, the slapping sounds may be audible from some distance.

Licking the fur was not common, although the chest and belly may have been licked when the muzzle was held against these parts. The tongue was rarely visible as the muzzle moved about in the fur, and there was no sustained licking of one area as seen in dogs and cats. The tongue was not used to clean the face, lips, or paws, even though an artificial feed, "Teralac",[1] stuck to the paws. Occasionally when preening, the otters appeared to chew or nibble at the fur of the chest and the forearms.

Reaction to handling: From the first moment of capture, the otters showed definite individuality of response to handling. The urge to escape dominated, and new captives were not ordinarily aggressive unless forcibly restrained or provoked. Generally the newly caught otter fought the net by twisting and rolling, and biting at it or any other object within range. Small animals of 18 to 25 pounds in weight required little restraint and usually lay sullenly on their backs with heads erect when cornered. This was not cowering but an alert defensive position from which the otter could rear or lunge to snap, often using its paws with surprising speed in an attempt to grasp an irritating object. A hand touching the neck or back of the head was easily grabbed, and if not quickly withdrawn, was scratched or bitten. Such attempts to bite were accompanied by hissing and rattling snarls but no prolonged growls.

Since the skin is extremely loose over the entire body, the otter can bite a hand holding it by the scruff. Small otters up to 25 pounds in weight were momentarily restrained by grasping the neck from behind with both hands although the snapping jaws came close to the fingers. When held in this manner, the paws and less commonly the flippers were used with considerable force against the hands.

[1]"Teralac", a dried milk-like substance, was supplied for this work by Chas. Pfizer and Company, Brooklyn, New York.

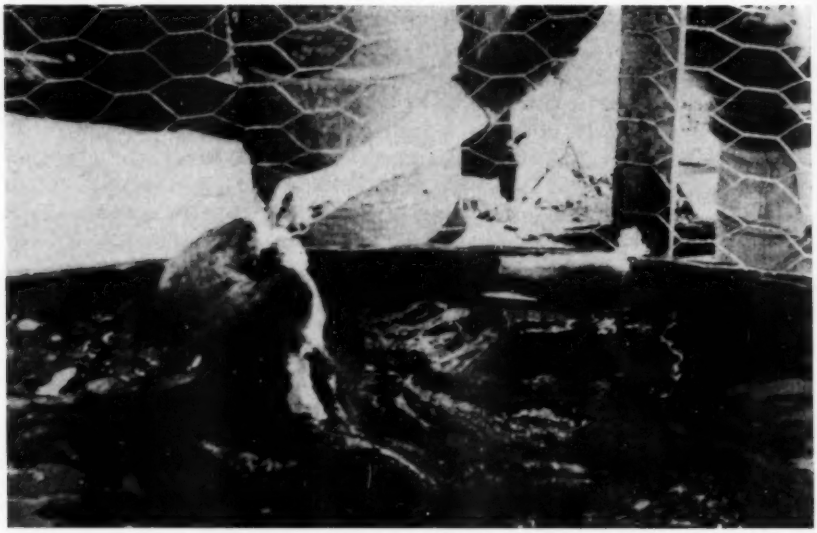

Fig. 3. Large male sea otter accepting food shortly after capture.

Men handling otters were occasionally bitten because of carelessness or inadequate protection of hands or arms. Resulting injuries were usually in the form of pinches which sometimes did not break the skin. Hortense was the most easily handled, probably because she received most attention, but even after three weeks of captivity she objected to being touched. Before being picked up, she was induced to bite and hold a mitten loosely covering the hand. While thus preoccupied she was lifted and gently cradled in the arms. As soon as her body was securely supported, she lost interest in biting and could be carried short distances or held for several minutes. Peter was less docile and Aggie resisted all handling violently.

After a few days in captivity, when not handled, the otters usually ignored people, movements, and sounds. Flash bulbs, lantern light at night, and unusual sounds (gunshot, carpentry, shouting, and whistling) elicited only passive interest. No signs of affection for man were noted, but the close presence of people was tolerated even to the extent of lying on their feet or resting against their legs while feeding. Hortense, the most active and curious, climbed upon persons while exploring, but any other human contact not self-initiated, such as petting or examination, was swiftly rejected.

Food and feeding behaviour: The remarkable fact that some wild sea otters accept food from human hands shortly after capture has been noted previously (Barabash-Nikiforov, 1938; Jones, 1951b). In 1954 the Amchitka otters kept at first in dry cages, did not immediately come forward for food, remaining on the defensive in a far corner. They would eat, however, if food was thrown to them or offered on a stick. One newly caught otter swimming

Fig. 4. Large male sea otter reclining to eat when hauled out in holding tank.

in the holding tank, approached an outstretched hand, took food in its paws or mouth (Fig. 3), and turned upon its back to eat in the usual manner (Fig. 4). Sea urchins and limpets tossed into the tank were retrieved by this otter with alertness and rapidity in quick dives, and held with one arm and the loose skin pouch while the items were eaten one by one. Another otter, on its first day in captivity, readily accepted pieces of goose and seal meat while resting on the rocks in the holding tank; clutching pieces of food beneath one arm, it tried to secure additional morsels offered to two other otters in the tank. This habit was also noted by Jones (1951b, p. 353).

Although the otters usually lay upon their backs to eat, apparently any position was satisfactory. Occasionally an animal lay on its belly with the head and upper body twisted to one side. In this position in the "otter house" straw frequently got into the mouth with the food and, although some might be withdrawn by the paws, it was commonly ingested and found in the feces.

During the early part of each otter's confinement, food intake was determined both by the supply available and its acceptability. Efforts were made to give the otters a variety of foods in order to find which were palatable or seemed to stimulate their appetites; not all foods were equally acceptable to the different animals and collecting sufficient quantities of palatable foods was a problem during stormy periods. Limpets, blue mussels, sea urchins, periwinkles, hermit crabs, and starfish were gathered in small quantities from rocks at low tide. An occasional octopus was taken clinging to a fish trap. However, fringed greenling (*Lebius superciliosus*), laboriously taken in live traps and long lines set in Constantine Harbor, made up the bulk of the diet for the

Fig. 5. Immature sea otters, after a few days in captivity, begging to be fed.

first few weeks, and this fish was consistently palatable. Small amounts of "Teralac" were added to the diet periodically.

The greenling, usually held in a live tank, were cut into small chunks and the bones of the heads and vertebrae were chopped fine. The spiny-rayed fins of large fish were discarded, and the viscera were divided among the otters to give a balanced diet. The otters soon learned the meaning of the fish bucket and the hand-axe used for chopping fish. Various begging attitudes were assumed, but for the first pieces the three animals would be directly underfoot or trying to climb up the leg of the person feeding them (Fig. 5). Chunks were grasped in the teeth, or in the paws if the otter was on its back. Larger fillets were held edgewise in the paws and strips of flesh pulled off with the incisors. The molars were used to crush bones and mash muscles. Small pieces of skin were thoroughly chewed and swallowed, but larger pieces were often cleaned of flesh and then discarded. In general the otters masticated their food much more thoroughly than most other carnivores; there was no gulping or "wolfing" of chunks.

Molluscs were eaten with relish. Small limpets, blue mussels, and snails were chewed up entire with loud crunching noises, and then swallowed. Larger limpets were usually extracted from the shells by holding the molluscs' flesh against the lower canines and pulling downward on the shell with the paws. If this was not successful, the shell was held with the paws at the side of the mouth and cracked by the molars; the pieces were then cleaned in the

same manner as the whole mollusc. Otters habitually cleaning shells this way would wear the anterior surfaces of the lower canines and incisors, as noted by Hildebrand (1954).

Octopus was a favourite food. When the tentacles were chopped into small pieces, the still-functioning suckers sometimes clung to the otters' faces or more often to their palates or pharynxes. This difficulty was met by attempts to scratch in the open mouth (similar to a dog's behaviour with a caramel in its mouth) or to pull out the tentacle with the paws; a morsel lodged farther down caused much gagging and hawking until it was dislodged, retrieved, and chewed again. The persistent efforts to chew and swallow octopus tentacles indicated their enjoyment of this mollusc.

The basis for differences in food acceptance was not clear, but individual condition and temperament were perhaps important factors. As already noted some very hungry, newly caught otters took goose and seal flesh and viscera from the hand, items usually rejected by otters in better condition; less trusting individuals refused any food in human presence. Although accustomed to captivity, one otter steadfastly refused starfish which were eagerly snapped up by the others, and Dolly Varden trout from a freshwater lake were refused by all. Hortense ate greenling skin and fins discarded by the others, posing the question whether she was more hungry or was simply less discriminating.

Captive sea otters were thought to be omnivorous by Barabash-Nikiforov (1938) who states that they will eat starchy products and pelleted foods as well as meat. Mal'kovich (1937) reported that cooked food was acceptable but the kind of food and method of cooking are not given.

Most of our observations on feeding behaviour were made on three otters during the first three weeks of captivity or on animals not surviving that long; tests with otters after longer periods of acclimatization might prove them less particular than short-term experience suggests. Sea otters certainly do learn to eat strange foods. When frozen flounder fillets (thawed) were offered to our animals, for the first week only one otter ate them, but within three weeks all were eating them and apparently preferring them to fresh whole greenling. Jones (1951b, p. 353) observed a preference for frozen halibut over native rockfish.

As a group the three Amchitka captives were fond of invertebrates but the few pounds we could occasionally gather with considerable effort merely diversified the main diet of greenling and frozen flounder. Later, when a fourth animal was added and the group was taken to Adak for several weeks, large quantities of live shrimp were included in the diet as well as chitons, urchins, and crabs, which were all more numerous than at Amchitka. At the Seattle Woodland Park Zoo, the three surviving otters accepted cod, ling cod, rockfish, smelt, and littleneck clams; squids were also eaten but octopus was less attractive than on Amchitka.

Well-conditioned otters consumed such quantities of fish and other marine life that it was often difficult to secure adequate supplies. When the passage of food through the alimentary tract was timed, by feeding a meal of molluscs to animals on a pure fish diet, it was found that it took an average of

Fig. 6. Two sea otters drinking from a tip-proof pan.

three hours for the shells to appear in the feces. This indicated a need for frequent feeding, and prompted the schedule given on p. 49. When fed approximately 2¼ pounds of fish and meat per animal per day (12 to 15 per cent of body weight), the otters occasionally passed the tarry feces indicative of enteritis. Later the rations were increased to about 7 pounds of fish per animal per day (25 to 35 per cent of body weight) and improvements in condition were noted at once—signs of enteritis disappeared, weights increased, and the otters became stronger (Stullken and Kirkpatrick, 1955).

On Adak the amount of food eaten by the four otters rose to 35 pounds per day, with fish comprising about 4/7 of the total. As the weight of all the otters was 98 pounds the daily food consumption was about 35 per cent of the body weight. Otters kept by Mal'kovich (1937) consumed from 7¾ to 18¾ pounds daily according to their size, or an average of 22.7 per cent of body weight; but young individuals, comparable to ours in weight, took 29 to 35 per cent of their weight daily while large adults took less—17 to 23 per cent.

Drinking: When water was first offered to otters kept in a dry environment, the animals attempted to get into the water and swim. The water in a bowl, pan, or bucket was usually tipped or pawed out, and wallowed in, making the provision of small quantities of water for drinking impractical; however, snowballs were acceptable substitutes. The otters held the snowballs in their paws and bit off, chewed, and swallowed small pieces; two snowballs the size of baseballs were often consumed without stopping. Later a large

tip-proof pan was provided with wooden guards to prevent the animals from crawling into the water (Fig. 6). Water one-half inch deep was lapped up while the lower jaw rested on the bottom of the pan; there was no head motion, and although the nostrils were not submerged, there was considerable bubbling and slobbering. When the water was deeper it was difficult to tell whether it was lapped or sucked up because the head was dipped in and swished about while one paw was swirled around in the pan. It is not known whether wild otters require drinking water, but the three captives held in a dry environment consumed about a gallon of fresh water daily. No conclusive observations were made to determine whether sea water would satisfy their water requirement. They did not appear to need salt and did not develop the cloudy eyes which occur in otarids held in fresh water. Of the Ostrov Mednyy captives seen by Hrdlicka (1945, p. 397), one had lived for three months in fresh water.

Locomotion: The peculiar hobbling gait of a sea otter is not unlike that of a land otter, though more clumsy. The head and hips are held higher than the shoulders, with the lumbar region arched even higher than the hips; the tail may drag or be held at an upward angle. Ordinarily, when not moving, the otters do not stand but drop to their bellies, sides, or backs.

At their usual slow gait, an otter's paws and flippers on opposite sides move alternately as in other fur-bearing animals. A laborious gallop is possible for short distances with both paws hitting together alternating with both flippers hitting together. When hurrying there is sometimes no co-ordination as the short fore legs are moved rapidly, together or alternately, and the hind legs are moved more slowly. At a slow walk, the flippers may be placed outward about 30 degrees from the line of forward motion and at other times the toes may be directed straight forward.

One otter was adept at climbing anything offering a purchase. It was never seen to leap straight upward, although it did attempt jumping from a cot to a higher table about two feet away, and frequently made downward jumps of about two feet.

Sociability: For the most part, the otters ignored each other when thrown together in the "otter house", but they evidently received moral support from the presence of other animals and conversely were depressed by isolation. At the beginning of her captivity, Hortense definitely disliked the small cage that did not permit her to wander at will or associate with people or other otters. On the shipboard trip from Amchitka to Adak, the four otters occupied separate but adjoining cages where they could see or smell one another but could not get together. They were restless and screamed. Later, when the three survivors were moved to Seattle, a large cage held them all, which was more satisfactory judging from their calm behaviour. It is possible that captive otters stimulate one another. One of our animals held in a tank enclosure alone refused food for twenty-four hours. As soon as two other otters were turned in with him he began feeding, though he remained quite shy. Mal'kovich (1937) notes that a single otter held in captivity for two months was lonely, but changed when a second otter was introduced. A sign

of mutual interest was that the second otter, being afraid of man and apparently concerned for the first otter, tried to protect him by dragging him into the water at the sight of man.

During the first few days of captivity, after learning to take food from human hands, the otters bickered for the same piece of food; no fighting or mauling of a serious nature, however, occurred in the common confines of the "otter house". In some instances the larger animal stole from the smaller but rarely bullied. On one occasion Aggie crawled upon Peter's belly and lunged for a fish in his paws which he quickly pulled back with a vocal *ha-ah-ah-ah*. Another time Aggie successfully grabbed a morsel from Peter who objected with a low, explosive *oof* as the fish was jerked away. His vocal objections to attempted thievery were usually a series of low, staccato grunts, *ugh-ugh-ugh*. Hortense, the smallest, was generally fed away from the others to prevent her being molested, and as long as there was more food at hand, the others seldom pursued and robbed her. Once Hortense herself stole food from a weak captive she had seen but a few minutes before.

The competition for food may have been the result of extreme hunger. Later, when the captives had gained weight and seemed in better physical condition, bickering at feeding time was rare and little competition marred their docile behaviour. When all the otters had food, they lay side by side or even leaned against one another while eating and tidbits could be fed to one otter within inches of another's nose without interference. They did not appear to seek direct contact with their pen-mates, and it seemed accidental that they sometimes rested against one another. No playing or any outward signs of interest between otters was observed.

Voice: The loudest vocal effort was a multi-syllabled shriek, variable among individuals, phonetically rendered as *eeee-eeee-eh*, or *eeee-eh*, or *eeee-er*. The first syllables were always high in pitch, given either with a quaver or as a clear, shrill shriek. The last syllable was short and grunt-like, in a much lower tone, and was inaudible at a distance of a few feet.

Captive otters in great distress, particularly moribund animals, uttered combinations of these sounds in high-pitched, ear-piercing screams. One young pup of 4¼ pounds cried continuously, giving utterance about every two seconds with a two-syllabled *eee-ee*, which at a distance resembled the mewing of a kitten. The otters might squeal at any time except when sleeping. Restlessness while calling usually seemed to indicate that they were hungry, thirsty, or lonely.

A series of low, soft grunts, *uh-uh-uh-uh*, were uttered by otters feeding together. Grunts of objection have been described as well as vigorous hawking in attempts to clear the throat. Other sounds made, in addition to the slapping already noted, included rumbling belches following eating and drinking, and audible flatus. Hiccupping commonly occurred but this was not accompanied by audible sound.

Elimination and sanitation: The otters showed no signs of establishing a midden or of fastidiousness in their excretory habits. Fluid or semi-fluid feces were dropped spontaneously. Defecation usually occurred in a standing

position, tail raised, rectum partially prolapsed, and was often accompanied with urination. The animals ignored the scats, treading on or avoiding them purely by accident.

Aggie, Hortense, and Peter, the subjects of most of the observations recorded here, were transferred from Adak to Seattle by motorship as deck cargo and were lodged temporarily in the Seattle Woodland Park Zoo on 1 June 1954. According to the report of Ford Wilke, a member of the research team, the otters "appeared in excellent condition" and spent a comfortable two weeks in a bear grotto with a pool 4 x 8 feet in size, constantly supplied with fresh water at about 50°F. They were then flown from Seattle to Washington, D.C. in a first class passenger aircraft pressurized to 5,000 feet, and delivered to the National Zoological Park on June 14. All three succumbed within ten days. The causes of their deaths are uncertain as none of the biologists responsible for their care up to June 14 were present, but the extremely high air temperatures at the time of their arrival in Washington, D.C. were presumably harmful.

In all phases of the 1954 investigation of sea otters on Amchitka, including our daily work with captive animals, we were dependent upon the invaluable support of William Golley, David C. Hooper, Calvin J. Lensink, and Ford Wilke of the U.S. Fish and Wildlife Service. Some of the notes for this paper were also contributed by Mr. Wilke, and these are gratefully acknowledged.

We are also indebted to the U.S. Fish and Wildlife Service for providing translations of the Russian articles cited in the references.

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INSULATING EFFECT OF A SNOW COVER ON THE GROWTH OF YOUNG SEA ICE*

B. E. Holtsmark†

In the spring of 1949 members of the U.S. Navy Electronics Laboratory stationed at the Arctic Research Laboratory of the Office of Naval Research, Point Barrow, Alaska, studied the effect of the thermal insulation of snow cover on the growth of that season's sea ice.[1] Twenty-one measurements of snow thickness made on fast sea ice are shown in Fig. 1. Under a snow cover of 10 cm. the ice was repeatedly measured to be about 180 cm. thick, whereas under 60 cm. of snow it was only 135 cm. thick. The relationship indicated here is not, however, an exact one. In nature the rate at which ice grows decreases as the thickness increases; therefore, it is reasonable to suppose that a hyperbolic type of relationship may exist between the thickness of snow and sea ice.

The scattered distribution of points measured for the ratio of snow thickness to ice was necessary because the snow cover at certain spots was too restricted to yield reliable values. For example, a snow mound one metre wide cannot effectively insulate ice 150 cm. thick.

During the late winter and early spring of 1950 the vertical temperature was measured daily with carefully calibrated thermistors at nine levels through a section of the air–snow–ice system on the young sea ice off Point Barrow. In addition, four control areas, with varying thicknesses of snow cover, were used to measure simultaneously the different amounts of ice growth.

Equipment

Measuring equipment consisted of a number of accurately calibrated thermistors (temperature-sensitive resistance elements) and a portable, heated Wheatstone bridge to determine thermistor resistance in the field, where air temperatures down to -50°C might be expected.

Nine thermistors were installed in a vertical section through the air–snow–ice system from 2 metres above the snow to a depth of 85 cm. into the ice.[2] The vertical spacing (Fig. 2) was arranged to obtain gradients through those layers of the system which, at that time, were believed to govern the heat flow.

The two thermistors above the snow were secured to a wooden mast one inch in diameter, securely guyed from the top and midsection with stout cotton

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†U.S. Navy Electronics Laboratory, San Diego, California.

[1]U.S.N.E.L. Oceanographic Studies Section. 1950. 'Oceanographic field observations in the Arctic near Point Barrow, Alaska'. *Report* No. 189, 12 pp.

[2]Nine thermistors were originally installed, but Nos. 16, 4, and 8 had to be replaced during the early part of the observations by three additional thermistors, Nos. 17, 11, and 12 (Fig. 2).

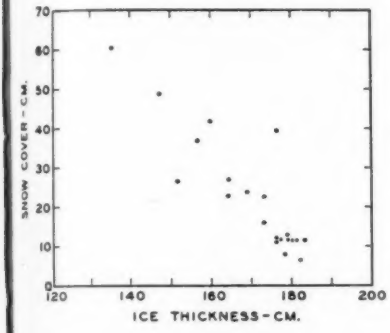


Fig. 1. Measurements of fast ice thickness and overlying snow cover.

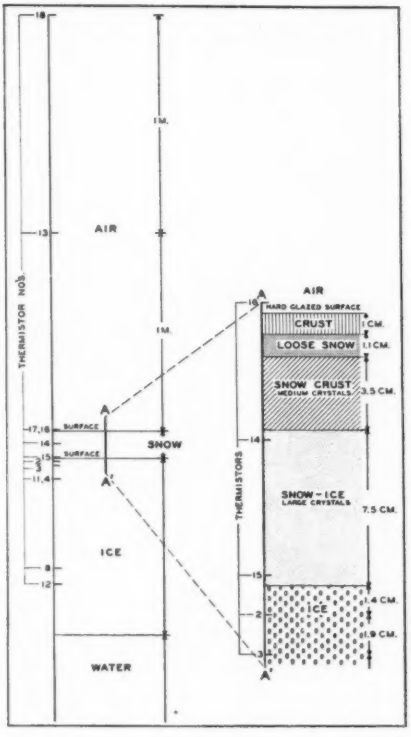


Fig. 2. Thermistor spacing through air–snow–ice system and schematic layering.

lines anchored in the ice with spikes (Fig. 5). The thermistors were fitted with adjustable metal shields, which could be regulated to give protection from direct sunlight.

A junction box was installed near the vertical section and all thermistor leads were gathered there to protect the contacts from icing. This precaution was found to be unnecessary, however, since if the ice did form on the metal plugs it was easily removed by hand.

The Wheatstone bridge was housed in a small, specially heated, portable plywood box measuring 10 x 6 x 4 inches. The bridge proper was in an inner plywood box with 1 inch of pressed cardboard insulation on all sides. All shaft connections with the interior of the box were micarta rods. The galvanometer dial face was covered with two glass plates separated by ½ inch of air insulation. The major source of heat loss was thereby restricted to the thermistor jack leads and connections for the electrically heated copper water tank. The water for this tank, which was also inside the box, was heated at the laboratory when the equipment was not in use and the heat capacity was sufficient to keep the bridge components warm for two hours of exposure to temperatures of the order of -40°C.

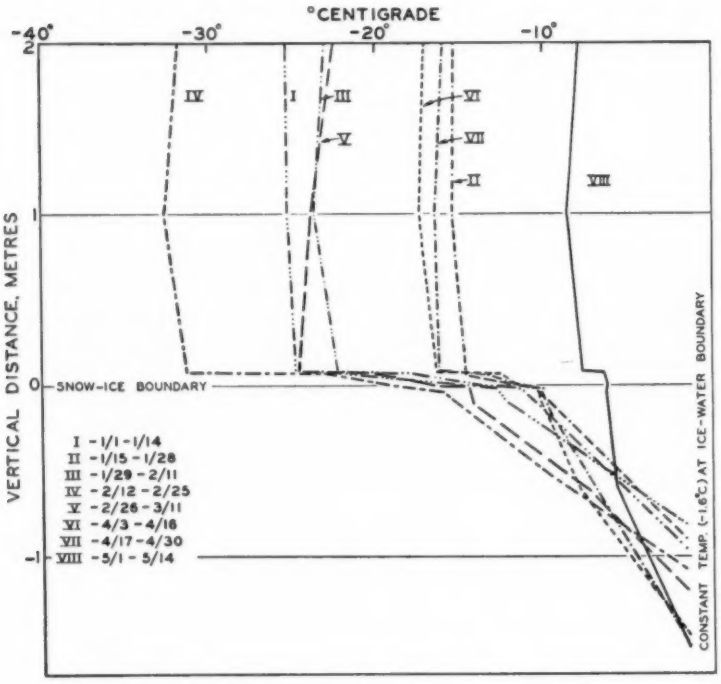


Fig. 3. Bi-weekly average temperature profiles through air–snow–ice system, 1 January to 14 May 1950.

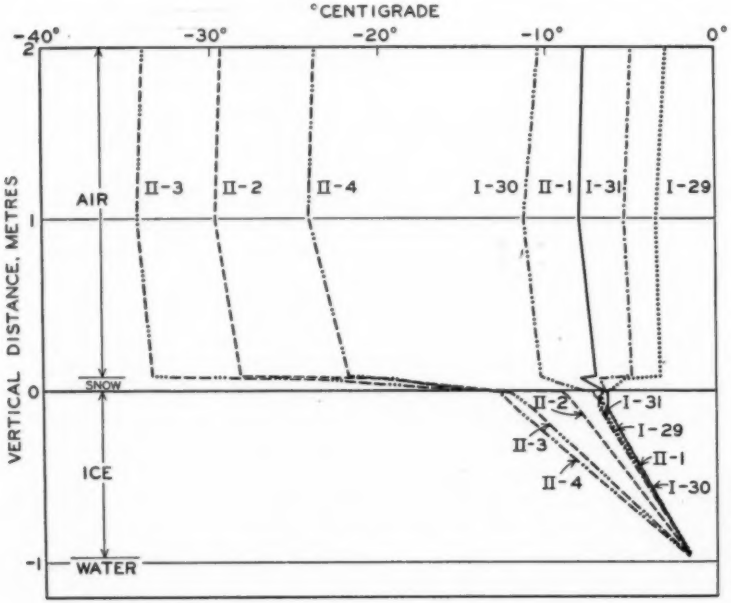


Fig. 4. Daily temperature profiles, 29 January to 4 February 1950.

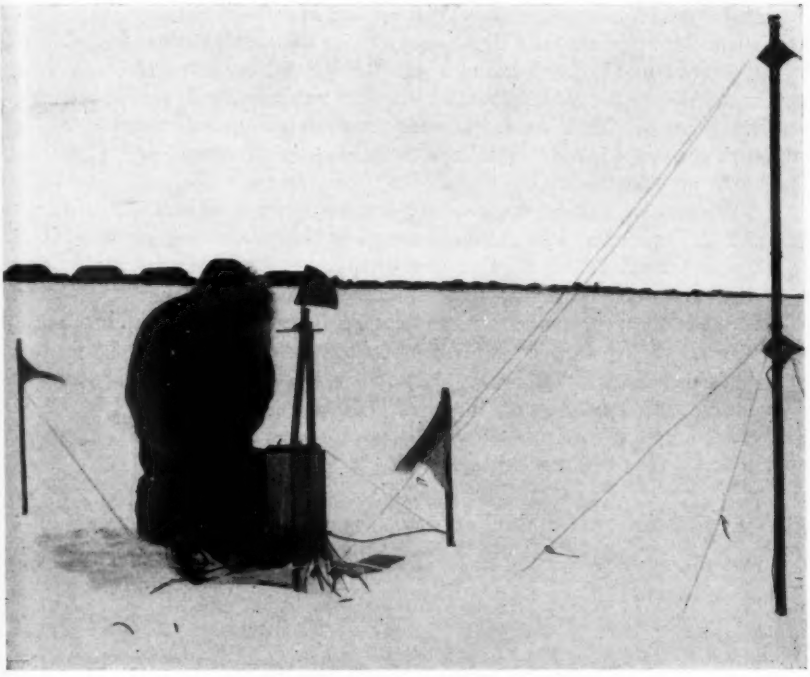


Fig. 5. Thermistor station on fast ice.

The reading of temperatures in the field was confined to selecting thermistors and rotating one potentiometer dial to balance the bridge. These operations could be performed easily with heavily mittened hands, and the thermistor resistances were recorded in air temperatures down to -42.3°C.

Measurements

Bi-weekly average temperature profiles are given in Fig. 3, and show that fluctuations in air temperatures decrease with distance from the air–snow surface. It can be assumed that at the extreme end of the system, at the ice–water boundary, temperature fluctuations reflect only possible variations of the freezing point of sea water. The latter, in turn, are dictated by variations in salinity: for example, a salinity of 30 per mille has a freezing point of -1.63°C, that of 32 per mille a freezing point of -1.74°C.

The lowest average air temperatures occurred during February, and the warmest at the end of the observation period in May. The effect of heat insulation through the 8-cm. thick snow blanket was impressive; for instance, while the air temperature above the snow cover fluctuated some 22°C (-10°C to -32°C), the temperatures 7 cm. below the air–snow surface fluctuated only 9°C (-7°C to -16°C). The most extreme case occurred on 11 February 1950,

when the air temperature 0.5 cm. above the air–snow surface was -42.3°C, and the air temperature at a depth of 7 cm. in the surface snow was -24.1°C, a difference of 18°C. Variations in the ice surface temperatures, while reflecting those of the atmosphere, show a time lag and are considerably less in amplitude. Thus, the extreme ice surface temperature recorded, -20.1°C, was on February 15, four days after the lowest temperature, -42.3°C, 0.5 cm. above the air–snow surface.

Typical daily vertical temperature distributions are shown in Fig. 4. On January 29 the air temperature had been close to the freezing point (-2°C to -5°C) for several days. At this time the air temperature was higher than that of the ice and hence heat was conducted from the atmosphere to the ice. A cold spell followed, and the air temperatures dropped. This fall in temperature was reflected in the ice surface temperature on the following day, January 30. Four days later, on February 3, the air temperature started to warm up. The ice surface temperature, however, fell for another day before rising. Toward the end of the season this process is reversed and heat from the air contributes to the melting of the ice.

Ice thickness and snow cover

Periodic measurements of snow cover and ice thickness were made at the thermistor station and at four control areas in the vicinity (Fig. 6). The latter measured 5 metres x 5 metres, as this was the largest area that one man could reasonably maintain.

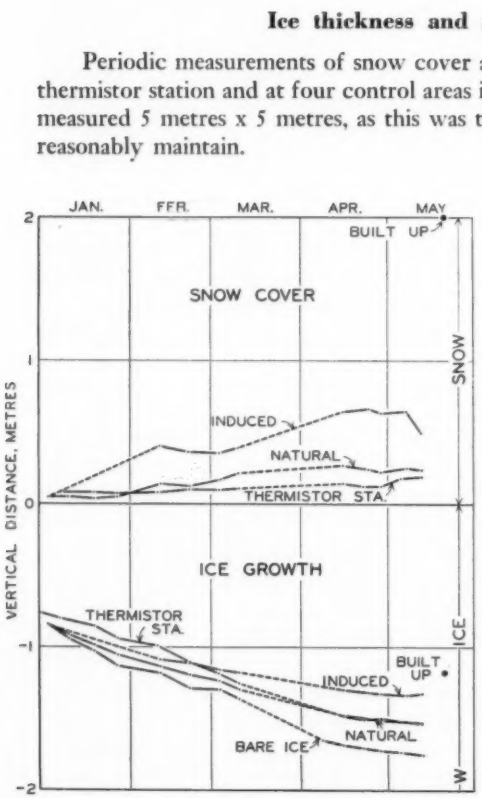


Fig. 6. Ice growth at thermistor station and four control areas.

The first control area was kept as free of snow as possible by daily shovelling. The second area was chosen to show natural snow cover and had to be free of surface irregularities which would cause surface drifts; it proved to be satisfactory, the maximum depth of snow cover reaching only 27 cm. Snow cover was induced upon the third control area by building a snow barrier one metre high, around which the drifting snow could accumulate to a natural maximum thickness; the induced snow reached a depth of 67 cm. Snow was shovelled on to the fourth control area throughout the season to obtain a maximum possible thickness. Progress was slow at first because of the scant snow deposit in January. However, as the pile grew in height drifts formed on the lee side and progress increased. When the pile had reached a height of 1.5 metres, a snow-block wall was erected around the area and snow was built up to a final thickness of 2 metres at the end of March.

Measurements of snow cover and ice thickness were made about once a week except in the built-up snow-cover area. It was undesirable to drill the latter until a maximum snow cover had been achieved. Then it was impracticable to do so without seriously disturbing the insulating properties of the cover. Therefore one drilling only was made in this built-up snow-cover area at the end of the observational period. In the other areas, no drillings were made during a period of forced inactivity, indicated with dashed lines in Fig. 6. The measurements show reasonably good agreement. Whereas the ice thickness varied by some 3 cm. between the thermistor station and the natural snow-cover area in January, at the beginning of the season, it was practically identical towards the end, in May. In the induced snow-cover area, where snow reached a depth of 67 cm., the ice thickness was 133 cm. The ice grew thickest in the bare-ice area, measuring 176 cm., and was thinnest under the built-up snow-cover, measuring only 117 cm. Even this crude method of measurement showed a 50 per cent increase in ice growth between the extreme snow depths. It is quite probable, moreover, that the ice under the built-up cover would have been even less if the 2 metre-thick cover could have been established at the beginning of the season. As it was, the ice had begun to sag under the snow load, as shown by the amount of water which poured over the ice surface as the measuring hole was drilled.

Periodic measurements of young sea ice growth in five areas, each with different thicknesses of snow cover ranging from nothing to 2 metres, show that a relationship exists between cover thickness and ice growth. The growth of the ice with no snow cover was nearly 50 per cent greater than that under 2 metres of snow. Because of the complex structure of the snow cover, however, a much more detailed study is necessary to explain fully the heat insulating phenomenon. Present knowledge is not sufficient to predict ice thickness from snow-cover thickness.

REVIEWS

EASTERN ARCTIC WATERS.

By M. J. Dunbar. *Ottawa: Fisheries Research Board of Canada, Bulletin 88, 1951. 10 x 6½ inches; 131 pages, maps, diagrams and tables. $1.00.*

This very complete and much needed compilation and review of oceanographic information on the Eastern Canadian Arctic comes from a man who is primarily a biologist. However, Dr. M. J. Dunbar is no stranger either to oceanography or to the Arctic, and he has produced here a valuable summary of a very large subject, as the list of nearly three hundred references readily shows. The introduction mentions that knowledge of the oceans is still qualitative rather than quantitative, and the paper, therefore, is "largely descriptive and only in small part analytic".

A project such as this poses the perplexing, thankless, and oftentimes embarrassing problem of deciding what data to accept and what to reject. In the section on "Bathymetry", for example, the author has treated a sounding of 2,870 fathoms in Baffin Bay as being erroneously deep. Most authorities on the subject will agree with this. In the reviewer's opinion the author would have performed a better service for oceanography had he been more reluctant to accept data "showing" the water at 100 metres depth in Hudson Bay to be several tenths of a degree below freezing point. The water in question had an observed salinity of about 33.20 per mille which has a freezing point of approximately -1.8°C. Even allowing for the reduction of the freezing point by a tenth of a degree due to the pressure per 100 metres, it is still difficult to believe that the *Loubyrne* data of 1930, which describe temperatures as low as -2.2°C at 150 metres can be accurate. The author writes that the data might be inaccurate, but he also tentatively puts forth the possibility, by way of explanation, that conditions in 1930 were different from those today. This may well be the case, but it does not explain the sub-freezing water temperatures. The author also suggests that the water may have lost heat *in situ* to the overlying layers or to the bottom. The *Loubyrne* data show the overlying layers to be warmer, not colder, and the possibility of losing heat to the bottom, especially to the extent of lowering the water temperature to below freezing point, seems most improbable.

The section on "Circulation" describes the generally accepted current pattern based primarily on the data from expeditions of the *Godthaab* and the U.S. Coast Guard. There is also an interesting discussion of the "North Water" of Baffin Bay—that area which surprisingly appears to remain unfrozen throughout most winters. Many individuals have considered this phenomenon and several explanations have been put forward, few of which satisfy anyone except the originator. A suggestion by Kiilerich, that rapid vertical circulation is responsible for keeping the North Water ice-free, is given some priority in Dr. Dunbar's paper. This theory is controversial, but until winter field work is carried out in the area, no theory can be proved correct.

This section also includes a short discussion of "feed-back" circulation systems, the subject of a separate paper by Dunbar in 1950.[1] According to the concept held, the excess pressures which may be exerted during fluctuation peaks of the North Atlantic Drift, for example, will be absorbed temporarily in the circulation of another area such as the Labrador Sea. In turn, Baffin Bay and Hudson Bay will help absorb excess pressure from the Labrador Sea.

[1] "Feed-back systems and oceanography". *Amer. Sci.* Vol. 38, pp. 599–603.

Under the heading "Fjords and other inlets", Dr. Dunbar discusses the differences between Greenland and Labrador fiords. Fiords are defined as being "deep inlets in the coast, usually (but not always) with a threshold in the bottom configuration at the mouth, with steep sides, and formed either by the action of glacier ice or by movements of the earth-crust, according to the point of view taken". Although the Labrador coast is greatly indented, true fiords are much less common than in Greenland.

Some earlier work by Hartley and Dunbar on the "brown zones", which occasionally occur on the surface of some fiords at the glacier face is also discussed. The brown-coloured zones are open areas within the brash ice, with a surface current away from the glacier face in the order of half a knot, and are caused by upwelling water. Planktonic crustacea are brought up from below, providing food for the many sea birds which cluster around the area. Hartley and Dunbar suggest that the driving force of this system is chiefly the melting of the brash ice. This is said to produce a surface layer of very fresh water which, in pouring out of the area, "demands" a replacement current of salt water to flow in below. The heavier inbound current brings up mud from the bottom along the glacier face and, reaching the surface, causes the brash ice to be pushed away from the glacier face. The melting of the brash ice would undoubtedly result in a certain amount of fresh water being formed at the surface, but that this should escape so rapidly and in such a way as to induce a strong replacement current from below does not seem plausible. Also there appears to be good evidence that the "brown zones" persist during the winter, which invalidates any theory requiring the melting of brash ice as an essential part of the driving mechanism.

The discussion of "Seasonal cycles" is necessarily restricted to those areas where winter observations have been made. It emphasizes our woeful lack of wintertime information throughout much of the Canadian Arctic. The section on "Long-term changes" is more informative. The history of the west Greenland cod fishery is an excellent indicator of these changes. Atlantic cod were caught on the west Greenland banks in the 1820's and again in the 1840's. By 1850 none was found in the area, and it was not until 1917 that Atlantic cod again appeared off Julianehaab. The cod moved north year by year until by the 1930's they had advanced north of Disko Ø. It is not yet clear whether the recent warming has come to an end, but the subject is of utmost interest scientifically and of great importance to the economy of Greenland.

The delimitation of Arctic and Subarctic is interesting and well handled by the author. Any attempt to arrive at a line which will satisfy everyone, even within a single scientific discipline, is likely to be little more than an academic exercise. Terrestrial boundaries based on winter, summer, or annual mean temperatures, the tree-line, the permafrost limit, isohyets, or combinations of several of these have been used by many. No single line will serve all purposes. A boundary based on terrestrial factors does not necessarily join, at the shoreline, one based on marine factors even though terrestrial and marine environments influence each other. Using physical criteria, the marine arctic is described as that area where only arctic water is found (arctic water being that originating in the upper two hundred metres of the Polar Basin). The marine subarctic is composed of a mixture of arctic and non-arctic water. It is recognized that the boundary-line varies seasonally, yearly, and over longer periods, but it is difficult using present methods to detect the presence of a given water mass near the border-line.

Biological indicators may be the most useful criteria in the establishment of a line of delimitation. For example, Atlantic cod are found abundantly near, but not in, pure arctic water. Similarly, a number of planktonic forms thrive in an area where arctic and non-arctic waters meet. The distribution of some inter-tidal littoral forms is influenced by

the weather over the land, as well as by the water bathing the shore-line, but they may still be valuable indicators. Using the general biological picture, the author has drawn a line of delimitation showing the east coast of Greenland, from about Angmagssalik, down to Kap Farvel and up the west coast to Kap York, to be subarctic. The east coast of Baffin Island lies in the marine arctic, and also the territory west of a line extending from the western tip of Foxe Peninsula diagonally across Hudson Strait to the west side of Ungava Bay. Hudson Bay itself is marked by a large question-mark. This line, while it will not satisfy everyone, appears to be a logical one for many arctic marine biologists and oceanographers.

As a summary of present knowledge of the area including the Labrador Sea, Davis Strait, Baffin Bay, Hudson Strait, and Hudson Bay, 'Eastern Arctic waters' is an essential reference work for all oceanographers and marine biologists with arctic interests.

WILLIAM G. METCALF

NORTH OF 55°.

Edited by CLIFFORD WILSON. *Toronto: The Ryerson Press, 1954. 9 x 6 inches; 190 pages; illustrations; maps and folding map. $5.00.*

Four times a year for almost two decades Clifford Wilson has produced *the* magazine of the North, *The Beaver*. Every issue has been filled with authoritative and entertaining articles, and the illustrations have been uniformly superb. Circulating far outside the still circumscribed group of northerners it has done much to attract attention to the rapidly growing significance of the north.

'North of 55°', a volume in the Ryerson Travel Books, is a symposium on the Canadian Arctic and Subarctic by sixteen authors, all of whom are recognized authorities. Although each member of the team has followed his own plan, the hand of the editor shows in the unity of the volume. Following a useful introduction by the editor, who attempts to escape being called a northern expert, there are chapters covering the land surface, exploration, climate, native peoples, mammals, fur trading, fishing, flowers and forests, birds, cultivation, geology and mining, travel in the old days and now, administration, more particularly by the R.C.M.P., and finally defence. This stark list of topics fails to reflect the variety of treatment offered–as for example in the chapter on travel a generation ago by P. H. Godsell, and in Andrew Croft's on modern transportation including various over-snow vehicles.

The Northland is changing fast and any author can be excused for not being quite up-to-date. Dr. J. L. Robinson wisely based his discussion of the climate on a series of temperature and precipitation maps. Unfortunately for his discussion, new data have appeared since his maps were prepared, (*see* 'Climatological atlas of Canada' by M. K. Thomas), and quite radical revisions must be made in some of the established distributions, and explanations based on them. This chapter also shows some discrepancy between text and maps, as for example when we read that Hudson Bay is, in summer, "a large body of cold water" which has a "major influence" on the climate of the area, only to find the 50°F isotherm for July apparently crossing it undeviatingly.

A double-page map designed to show the contrast between the drainage patterns of the Precambrian Shield and the Interior Lowlands is also unsatisfactory. It is evidently a reproduction of information plotted on to the 8-mile sheets at the Defence Research Board and most readers will find that it does not show the intended contrast clearly. A difference in drainage pattern exists, but the change does not take place at the edge of the Precambrian Shield. Perhaps by selecting part of the map only, with suitable orientation and labelling, the story would be told more clearly. The editor has included sufficient maps to help the reader not familiar with the area. There is, for example, a good "physiographic diagram" type of map, which must have required considerable detailed work by cartographer P. G. Downes.

Some other and unknown cartographer has served the editor less happily, in executing a folding map intended, probably, to show place names. The map has no scale, much of the print is extremely small, and there seems to be a lack of system in the names shown. Thus Mould Bay finds a place but not Arctic Bay; Alert is marked but not Pangnirtung, and there is a railroad to Lynn Lake, but not to Churchill. Goldfields survives but not Mayo, and the Eastern Arctic is nameless except for the most recent weather stations. The coast of Greenland, less Disko Ø, is a stylized bit of wriggly fretwork. The inclusion of this folding map, which pulls out for use during reading, is an excellent idea, but the execution is lamentable.

The thirty pages of well chosen photographs are technically magnificent. Well known photographers who have contributed prints include Richard Harrington, George Hunter, and R. N. Hourde. Better known in other ways, but also skilled photographers, are A. E. Porsild, J. W. Anderson and L. A. Learmonth. The photograph by Geo. White of H.M.S. *Alert* caught in the ice of Robeson Channel in August 1876, while returning from the polar sea, is excellent. It might well be hung in every air station of the far north to illustrate the conditions under which arctic pioneers worked. Many chapters contain references to the scientific contributions of early expeditions, so that the reader of 'North of 55°' does not get the impression that "opening up the North" has been a postwar undertaking.

Perhaps the most illuminating chapter is that by Dean Grant MacEwen, entitled "Food from the soil". It has often been thought that the abundant bare rock of the Northland would eventually, if only by the law of averages, produce minerals of economic worth. What, until recently, has been less apparent is that in some areas the soil too can bring its rewards. In spite of work done at Fort Vermilion as early as 1886, when there were no railroads north of Calgary, the possibility of producing fresh food for local use throughout the Mackenzie valley is still not generally recognized. Perhaps attention could be called to it by some University granting an honorary degree in Agriculture to Mr. Browning who has made a living by horticulture near Fort Simpson for the past thirty years!

In concluding this review of an excellent book, which deserves to be read widely, special mention should be made of the drawings of wildlife by Clarence Tillenius and Terence M. Shortt. Northern residents unskilled in such matters will be specially appreciative of the interest they add to life 'North of 55°'.

TREVOR LLOYD

THE NAVIGATOR'S POCKET ALMANAC, 1955, FOR AIR AND SEA NAVIGATION AND ASTRONOMICAL SURVEYING.

By PAUL E. WYLIE. *The Institute of Navigation, University of California, 1954. 9¾ x 6¾ inches; 22 pages; tables and diagrams.*

There are many almanacs current for one year, and almost all of them are large and bulky. The 'Air almanac', for example, covers one year in three editions, each valid for a four-month period. Mr. Wylie's pocket almanac, while current for one year, is small, very compact and well laid out, but still contains the essential information in a readily available form.

'The navigator's pocket almanac' is mainly for use in calculating the Greenwich Hour Angle, the declination of the sun, Venus, Mars, Jupiter, Saturn, and Aries, and in determining the approximate times of sunset and sunrise. A table of Sidereal Hour Angles and Declinations for navigation stars is also included. The hour angle for 00 00 hours for each Greenwich date is tabulated, and "Hourly difference" values are listed for both hour angle and declination; thus several calculations are required to determine the local hour angle and declination of a body for any given time.

The pocket almanac appears to be very suitable for sea navigation and for use by most land parties. However, in

air navigation where time is at a premium, and frequent astronomical observations are necessary, the additional steps in computing hour angle and declination are very time consuming. Also, on long flights, where fatigue becomes an important factor, errors creep in if computations are not reduced to a minimum. Hence, for general use in the air, it is questionable whether including one year's data in a very condensed form, at the sacrifice of simple tables from which information can be extracted with practically no calculations, is desirable. Most navigators will probably still prefer the 'Air almanac'.

By omitting tabulations of the moon, considerable space has been saved. This may not be a handicap when the pocket almanac is used by land parties and in sea navigation, but in air navigation it is a limitation as the moon is used for heading checks and position fixing, especially when full, and when diffused cloud or haze makes star-sighting difficult. Except for the sun, the moon is the only body which can be sighted during the continuous daylight of the arctic summer. Thus the omission of the moon tabulations limits the usefulness of the almanac in high latitudes.

Many sea navigators and land travellers will find 'The navigator's pocket almanac' very convenient. Many air navigators will want to keep one with their equipment for the time when they are caught without a current edition of the 'Air almanac', which is all too frequent.

K. R. GREENAWAY

INSTITUTE NEWS

Appointment of Mr. T. H. Manning as temporary Executive Director

On 1 April 1955 Mr. T. H. Manning was appointed temporary Executive Director of the Institute. Mr. Manning, who lives in Ottawa, has travelled extensively in the Canadian North and has a wide and intimate knowledge of arctic matters. His main interests are in mammalogy and ornithology, but he has also made important contributions in hydrography and other surveys and has published many papers dealing with these subjects.

Mr. Manning was born in England in 1911, and first travelled in the north in the summer of 1931 when he visited the Faeroe Islands and Iceland while an undergraduate at Cambridge University. The next year he spent the summer and following winter travelling on foot and with reindeer in northern Norway, Sweden, Finland, and Russia. It was in 1933 that he first came to northern Canada and remained for two years surveying Southampton Island under the auspices of the Royal Geographical Society and collecting birds and mammals for the British Museum. Since then he has lived in the Canadian North for either the summer or winter of practically every year, on many occasions being accompanied by his wife.

Some of the expeditions Mr. Manning has led have been private, such as the British Canadian-Arctic expedition of 1936–41 on which much of the west coast of Baffin Island was explored, and others government, such as the Geographical Bureau's *Nauja* expedition, which explored the newly discovered islands in Foxe Basin, and two expeditions under the auspices of the Defence Research Board to the Western Arctic, one in the *Cancolim* in 1951 and the other the circumnavigation of Banks Island by canoe in 1952–3. In 1953 his vessel was the first to pass through M'Clure Strait.

During the war Mr. Manning served in the Royal Canadian Navy, and special use was made of his northern knowledge. He was seconded to the U.S. Army Engineers in connection with the siting and construction of Southampton Island airfield and to the Geodetic Service for

northern surveys, and he was attached to the Banting Institute for work on protective clothing.

Mr. Manning was awarded the Bruce Memorial Prize in 1944 by a joint committee of the Royal Society of Edinburgh, the Royal Physical Society, and the Royal Scottish Geographical Society, and in 1948 received the Patron's Medal of the Royal Geographical Society. He has been closely associated with the Arctic Institute for many years and was Chairman of the Board of Governors in 1952.

Award of research grants for 1956

The Institute is offering a number of research grants in 1956 for scientific investigations dealing with the arctic and subarctic regions. Priority will be given to field investigations in North America or to studies at one of the Institute offices.

Applications for research grants will be considered from those who have demonstrated their ability to conduct research work of superior quality in some field of science. Proposals in the broad field of the earth sciences, in marine biology, and in physiology are specially desired. Facilities of the Arctic Research Laboratory at Barrow, Alaska are available for a limited number of scientists for both summer and winter investigations. The facilities include both housing and equipment.

Application forms may be obtained upon request to: Arctic Institute of North America, 3485 University Street, Montreal 2, Que., Canada, or 1530 P Street N.W., Washington 5, D.C., U.S.A.

Completed applications should be received before 1 November 1955. Late applications will be considered in special circumstances only or if additional research funds become available. The research grants will be awarded on the recommendation of the Board of Governors of the Institute and will be announced not later than March 1956.

The Institute is also in a position to award grants from a sum of money provided by the Trustees of the Banting Fund primarily to encourage Canadians, particularly recent graduates, in northern studies. Inquiries should be addressed to: T. H. Manning, 37 Linden Terrace, Ottawa 1, Ont., Canada.

McGill University-Arctic Institute Carnegie Program

The 1954–5 Carnegie Fellow, A. Bursa, spent the winter at McGill University and the Institute working on the phytoplankton samples collected in the Arctic by the Fisheries Research vessel *Calanus*.

The 1955–6 Fellowship has been awarded to Jean Corbel of Lyons and Paris universities, who has had previous field experience as a geographer in Spitsbergen and Greenland. He plans to spend the winter in Montreal and to do field work in the Canadian Arctic during the summer of 1956.

This summer six scholars are doing field work in the north:

F. A. Cook, Geography, Canadian Citizen: Studying patterned ground and physical properties of permafrost at Resolute Bay, Cornwallis Island.

J. D. Ives, Geography, U.K. Citizen: working at McGill Sub-Arctic Research Laboratory at Knob Lake, Quebec.

A. W. Mansfield, Zoology, U.K. Citizen: Research on the walrus in northern Hudson Bay.

Fritz Müller, Geography, Swiss Citizen: Research on pingoes and groundwater circulation in the Mackenzie delta.

D. R. Oliver, Zoology, Canadian Citizen, and

G. Power, Zoology, U.K. Citizen: Studying freshwater biology of subarctic lakes.

Five Scholarships have been awarded for the winter 1955–6 with summer field work in 1956:

G. Arundel, Economic Geography, U.K. Citizen.

P. D. Gabbutt, Zoology, U.K. Citizen.

J. P. Johnson, Geography, U.S. Citizen.

A. H. Macpherson, Zoology, Canadian Citizen.

J. G. Thomson, Zoology, Canadian Citizen.

'Arctic bibliography'

Two more volumes of 'Arctic bibliography' have now been published by the U.S. Government Printing Office. Volume 4 was published in August 1954. It lists and describes the contents of 7,627 books, articles, and papers in all fields of science relating to the arctic and subarctic regions of America and Eurasia. The entries, arranged alphabetically by author, are numbered consecutively from 20,004 to 27,631, the earlier entries being those contained in Volumes 1 to 3. Volume 4 has a subject-geographic index of 382 pages, in which publications are listed by topic and sub-topic and also under 69 major geographical areas –shown on a map–as well as under particular geographical localities or features such as rivers, bays, seas, islands, lakes, and towns. This volume contains proportionately more Russian, Scandinavian, and Finnish material than did the three earlier volumes. Special emphasis has been given to medical and biological subjects.

The fifth volume of 'Arctic bibliography' was published in April 1955. It analyses 5,494 publications in 1,268 pages, and has a subject-geographic index of 280 pages. The index arrangement in this and the preceding volumes is such that with a minimum of effort the reader can find listed and described the more important publications on any arctic or subarctic locality or area. Volume 5 gives special emphasis to health and disease, physiology, environmental effects, and anthropology, particularly of the native peoples of northern Eurasia. About 40 per cent of the publications analysed in this volume are in English, 30 per cent in Russian, and the rest mainly in German, the Scandinavian languages, Finnish, and French. Titles of foreign language publications are given in the original and in English, with the descriptive summary in English. Among the papers abstracted is the series entitled 'Fauna SSSR', published during the past forty years by the Zoological Institute of the Academy of Sciences of the U.S.S.R.

Material for Volume 6, compiled during the past year, will be given to the printer in June 1955. Covering all fields of science for the arctic and subarctic regions of the world, the 'Arctic bibliography' is the most comprehensive regional, annotated bibliography ever assembled.

'Arctic bibliography' has been prepared by the Arctic Institute for the U.S. Department of Defense under the direction of Miss Marie Tremaine, who has served as Editor and Director of the project since its inception in 1947. A Directing Committee, of which Dr. Henry B. Collins is Chairman, has exercised general supervision.

'Arctic bibliography' can be obtained from the U.S. Government Printing Office, Washington 25, D.C. The price of Volumes 1 to 3, totalling 4,478 pages (sold in sets only) is $12.75; Volume 4, 1,591 pages, is $5.50, and Volume 5, 1,268 pages, is $4.75.

The Institute Library

In the ten years since the Institute was founded, its library, which is housed at the head office in Montreal, has grown rapidly and is now one of the most important arctic libraries on the continent. It has proved its worth both to scientists and students and to industry. However, it is clearly impossible for a library of this type to subscribe to many foreign or specialized scientific journals in which papers dealing with the Arctic occur only occasionally. Fellows, Associates, grantees, and their friends are therefore urged to send reprints of their papers on arctic subjects to the library at 3485 University Street, Montreal 2, Que. In future, all such gifts will be acknowledged in *Arctic*.

Copies of Vaino Tanner's work on Newfoundland-Labrador

The Montreal Office of the Institute still has for sale 10 copies of Volume 1 of V. Tanner's 'Outlines of the geography, life and customs of Newfoundland-Labrador', price $3.00, and about 100 copies of Tanner's 'A bibliography of Labrador', price $1.50. Volume 2 is now out of print.

Photo: A. E. Porsild

View from cliffs northeast of the Danish Arctic Station showing Godhavn in the background.

NORTHERN NEWS

The Danish Arctic Station at Godhavn

The Danish Arctic Station at Godhavn, west Greenland, is the oldest permanent biological laboratory in the Arctic. It was founded in 1906 by the botanist Morten P. Porsild, with funds provided by private sources, mainly a grant of 35,000 Danish Kroner given by the publisher A. Holck. The station was at first associated with the University of Copenhagen, but in 1917 its administration was transferred to the Grønlandsdepartementet (then Grønlands Styrelse), and an annual grant, at first of 10,000 Danish Kroner, was made to cover all expenses. This arrangement continued until 1 April 1953 when the station was again taken over by the University of Copenhagen. The Faculty of Natural Sciences was made responsible, and has appointed a board of three professors to administer the station. They are, at present, Knud Jessen, R. Spärck, and M. Westergaard.

The station is built on the shore of Disko Bugt, a mile east of the town of Godhavn, at the foot of low gneiss hills, behind which terraced basalt cliffs rise to a height of over 2,000 feet. In 1928 the original building was enlarged to make room for the growing library, and in 1949 a second building was added, which is occupied by the scientific leader.

There have only been three scientific leaders of the station. In 1947, after forty-one years at the station, Morten P. Porsild retired and now lives in Copenhagen. He was succeeded by Poul Gelting, who was at that time biological adviser to the Grønlandsdepartementet. Poul Gelting continued as scientific leader until 1 April 1954. During his stay in Greenland he made a large collection of lichens which he is now working up at the University of Uppsala. The present scientific leader is Ulrik Røen, the zoologist. He is making a survey of the freshwater lakes in the Disko Bugt area. Orla Jensen is the superintendent of the buildings, and the library is supervised from Copenhagen by Knud Jakobsen.

The station is open to foreign scientists who want to study biological problems. They can travel by ship from

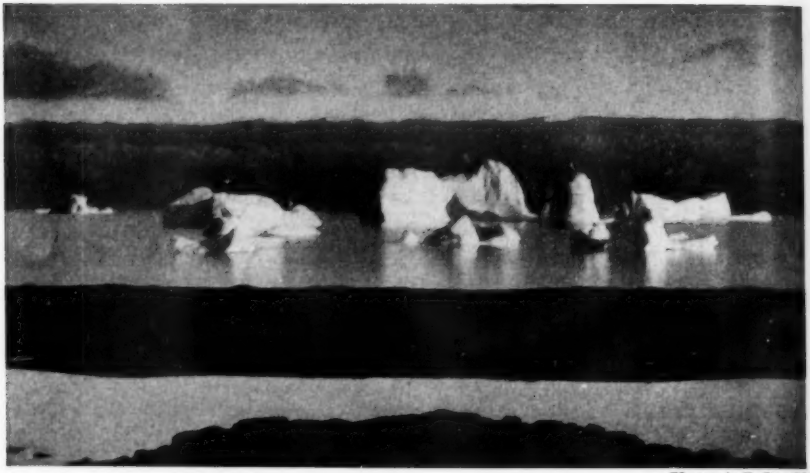


Photo: A. E. Porsild

Icebergs in Disko Bugt seen from the laboratory of the Danish Arctic Station.

Copenhagen to Godhavn. The first ship for Godhavn usually leaves Copenhagen in April, and the last returns in November. There is accommodation for up to twelve visiting scientists at the station. Visitors will be given free access to the facilities of the station, which has electricity (220 volts a.c.), standard scientific equipment, including microscopes, and a 36-foot sea-going boat, the *Holck*. Board and lodging are provided for about 10 Danish Kroner a day.

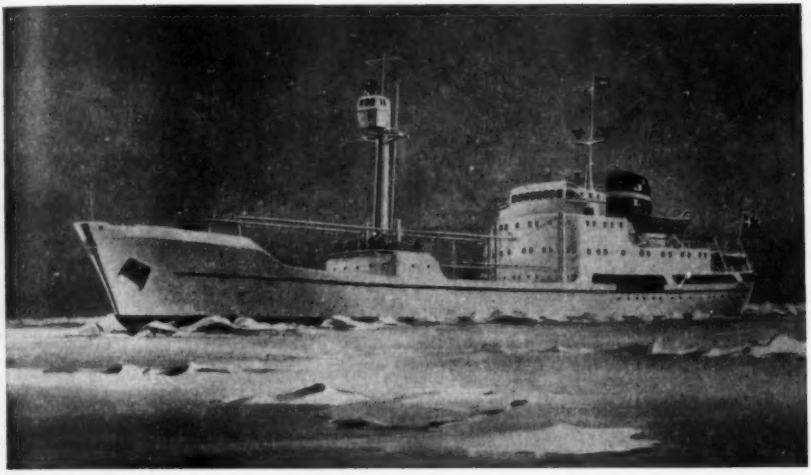
Scientists who want to work at the station should apply not later than February 1 of each year. They should state their research program, the length of stay, and the kind of facilities required for their work (instruments and books). Applications and all correspondence concerning the station should be addressed to: Universitetets Arktiske Station, Frue Plads, Copenhagen K, Denmark (Cable address: Arktostat Copenhagen). The address of the station in Greenland is: Universitetets Arktiske Station, Godhavn, Greenland (Cable address: Arktostat Godhavn). All correspondence concerning the library, including posting of books, periodicals, and reprints, should be sent to the Librarian, Universitetets Arktiske Station, L. E. Bruunsvej 10, Charlottenlund, Denmark.

Foreign scientists must observe all the regulations for visitors to Greenland, such as a medical examination, and must obtain permission from the Grønlandsdepartementet if they wish to make collections in Greenland. These regulations are given in "Bekendtgørelser om rejser til og i Grønland" (Orders on travels to and in Greenland, issued by the Danish Prime Minister's Department, 22 March 1954). Passport and visa regulations are the same for Greenland as for Denmark.

M. WESTERGAARD

New Danish arctic ship

J. Lauritzen Lines, Copenhagen, which for many years have specialized in transport in northern waters, have begun the construction of another arctic ship at their Aalborg Yard. The new ship is to be bigger and considerably more powerful than their vessel M.V. *Kista Dan*, 1,100 tons deadweight as a cargo vessel, speed 12 knots, which was built in 1952 for passenger and cargo transport in the Arctic and Antarctic, and is considered one of the strongest and most efficient



Drawing of the M.V. *Kista Dan.*

ice-breaking commercial vessels in service today. She has been used in east Greenland waters and, in 1954, was chartered by the Australian government to establish the Australian National Antarctic Research expedition on the coast of Mac-Robertson Land. The new ship, M.V. *Magga Dan*, will incorporate the experience gained with the *Kista Dan*. The *Magga Dan* will have a deadweight of about 1,650 tons as a passenger vessel, with a diesel engine giving a speed of 12 knots and a range of 16,000 miles, and will be ice-strengthened with heavy underwater shell-plating one inch thick. She is to have a special "ice-knife" aft, to protect the rudder when going astern, and three "ice-fins" will be fitted on each side of the underwater hull aft to protect the propeller from ice damage. The propeller will have a variable pitch, giving the *Magga Dan* more ice-breaking power for a limited period than a ship equipped with ordinary fixed-blade propeller; it will be controlled from the steering house or mast. There will be an enclosed navigation house (crow's nest) at the top of the foremast which may be reached from inside through the hollow mast.

The new vessel will have insulated holds which can be heated and kept frost-proof under arctic conditions, or cooled down to -20°C under tropical conditions. There will be cabin accommodation for 35 passengers. The *Magga Dan* will be ready for delivery about September 1956 and, with the exception of naval icebreakers, will probably be one of the strongest arctic ships in existence.

Kamchadal culture and its relationships to the Asiatic and New World populations

Although the inhabitants of the Poluostrov Kamchatka (Kamchatka Peninsula) have figured prominently in speculation concerning the relationship of Asiatic and New World populations, particularly with reference to the possibility of cultural diffusion or even movement of peoples from Asia to the Aleutian Islands, there has been no single source of data sufficiently comprehensive to be useful for examining these problems. This lacuna has now been filled by the recent study of C. S. Chard ("The Kamchadal: a synthetic sketch", *Kroeber Anthropological Society Papers*, Nos. 8 and 9, 1953, pp. 20–44). The author presents the relatively inaccessible source material of Steller and

Krasheninnikov, he corrects the simplistic view, commonly held since the Jesup expedition, of the Kamchadal as an "Americanoid" culture, and he presents a basic inventory of Kamchadal culture ranging from the ecological base to beliefs concerning the supernatural. The importance of the annual salmon runs in laying the basis for sedentary life and creating considerable leisure is well demonstrated. The extensive use of vegetable foods and of birds, and the minor role of land animal hunting is presented, with more importance given to sealing than has formerly been acknowledged. No evidence is found that whale were ever hunted. The absence of skin boats, kayak or umiak, with dependence upon wooden boats goes far toward explaining the failure to make use of the great sea mammal resources of the nearby Komandorskiye Ostrova (Commander Islands). The absence of polished slate implements, the apparent absence of native pottery, and the absence of drums are among the puzzling features which have important ramifications for theories of contact with the New World. Prior to 1740 it appears that the Kamchadals had no knowledge of or contact with the world outside Kamchatka except for limited trade contacts with neighbours to the north and south. Though origins and affinities of this culture remain obscure, it seems possible to exclude the Kamchadals as important contributors to Aleut, Eskimo, or Indian cultures of the New World.

WILLIAM S. LAUGHLIN

Symposium on Arctic and Alpine Tundras

A Symposium on Arctic and Alpine Tundras is to be held in connection with the National Convention of the American Institute of Biological Sciences in East Lansing, Michigan, Thursday September 8. The main speakers and the titles of their papers are listed below. The symposium will be held in Room 326, Natural Science Building, Michigan State College, and will start at 9.00 a.m. Further details can be obtained from John E. Cantlon, Department of Botany, Michigan State College, East Lansing, Michigan.

a.m. Pierre Dansereau, presiding.

A. E. PORSILD, National Museum, Ottawa, Ont. Age and history of the flora of the North American Arctic Archipelago.

WILLIAM C. STEERE, Stanford University, Stanford, Calif. Bryophytes in arctic vegetation.

CHESTER A. ARNOLD, University of Michigan, Ann Arbor, Mich. Some aspects of arctic paleobotany.

DANIEL A. LIVINGSTONE, Dalhousie University, Halifax, N.S. Pollen diagrams from arctic Alaska.

p.m. John Cantlon, presiding.

JOHN C. F. TEDROW, Rutgers University, New Brunswick, N.J. Soils and soil formation in permanently frozen arctic tundra.

JOHN H. CONOVER, Blue Hills Observatory, Cambridge, Mass. Macro- and micro-climatology of the Arctic Slope of Alaska.

JOHN W. MARR, University of Colorado, Boulder, Colo. Alpine tundra environment of the Front Range, north central Colorado.

HERBERT C. HANSON and ETHAN D. CHURCHILL, Catholic University of America, Washington, D.C. The concept of climax in arctic and alpine vegetation.

FRANK A. PITELKA, University of California, Berkeley, Calif. High arctic tundra as an ecosystem.

GEOGRAPHICAL NAMES IN THE CANADIAN NORTH

The Canadian Board on Geographical Names has recently adopted the following names and name changes for official use in the Northwest Territories. For convenience of reference the names are listed by the maps on which they may be found. The latitude and longitude given are approximate only and refer to the first letter of the name except where a precise location is given for a place or a spot height for a mountain.

Bathurst Inlet, 76 N.W. and 76 N.E. (8 miles to 1 inch)

(Adopted 3 December 1953)

Algak Island	67°32N.	108°25W.	not Algak (Adjgak) Island
Barry Islands	67 35	108 22	not Barry Island
Baychimo Harbour	67 43	107 56	not Bay Chimo Harbour
Belanger Rapids	66 03	111 12	not Belanger's Rapids
Brown Sound	67 26	108 28	not Brown's Passage nor Brown Channel
Chapman Islands	67 57	109 26	not Chapman Island
Cheere Islands	67 42	108 56	not Cheere Island
Ekalulia Island	67 37	108 05	not Barrys Isle nor Barry Island
Everitt Point	67 41	108 05	not Point Everitt
Fishers Island	67 57	108 10	not Fisher's Island nor Fisher's Islands nor Fisher Island
Goulburn Peninsula	67 24	108 26	not Goulburn's Isles nor Goulburn Island
Hackett River	66 04	108 20	not Dent River
Kenyon Lake	66 29	107 17	not Troughton Lake
Overby Lake	66 41	105 40	not Kelly Lake
Peacock Hills	66 02	110 56	not Peacock Mountains
Rideout Island	67 18	107 47	not Rideout's Island
Stockport Islands	67 48	108 59	not Stockport Island nor Stockport Isles
Willingham Hills	66 00	111 27	not Willingham Mountains
Young Islands	66 59	108 03	not Young Island

(Adopted 14 January 1954)

Mara River	66 27	108 38	

Hazen Strait, 79 S.W. and 79 S.E. (8 miles to 1 inch)

(Adopted 6 June 1952)

Cameron Island	76°37N.	104°21W.

M'Clure Strait, 98 N.E., 88 N.W. and 88 N.E. (8 miles to 1 inch)

(Adopted 4 June 1953)

Antler Cove	74°28N.	120°50W.
Cora Harbour	74 23	124 30
Mottley Island	74 04	119 05
Phillips Island	74 11	124 49

Ogden Bay, 66 N.W. and 66 N.E. (8 miles to 1 inch)

(Adopted 2 April 1953)

Discovery Lake	67°35N.	101°47W.
Gavin River	67 39	102 00
Highland Lake	67 22	102 05
Winter Island	67 42	102 20

Upper Back River, 76 S.W. and 76 S.E. (8 miles to 1 inch)

(Adopted 14 January 1954)

Mara River	65°53N.	108°47W.	
Nose Lake	65 26	108 57	not Mara Lake (as shown on map)

Photo: Karsh, Ottawa

OBITUARY

R. C. Wallace (1881–1955)

By the death of Dr. Robert Charles Wallace on 30 January 1955, the Arctic Institute of North America lost more than its Executive Director. The staff and the Governors lost a warm friend. The north lost one who knew it well and who had served it faithfully in a variety of ways during his forty-five years in Canada. So well and so affectionately was he known as "Wallace of Queen's" that his links with the north of Canada were somewhat naturally overshadowed in the minds of many of his friends. To some it seemed strange that, after his distinguished service to Queen's University, and at a time in life when many men would have cast all official duties aside, he willingly accepted the invitation to serve the Arctic Institute in its senior administrative post. But those who knew him well were not surprised nor were they in any doubt that what was supposed to be a "half-time job" was to be for him a labour of love upon which no time limit could be imposed.

He was a native of the Orkney Islands and a graduate of the University of Edinburgh, coming to Canada in 1910. In his native town of Kirkwall stands the ancient Cathedral Church of St. Magnus. And in a quiet corner of that old stone church is the tomb of another Orkneyman, another graduate of Edinburgh, a man who left an indelible mark upon the arctic lands of Canada—the tomb of John Rae. Dr. Wallace has himself told of the close links between the Orkneys, and Kirkwall in particular, and the Canadian North, mainly through the many men there recruited for the service of the Hudson's Bay Company, and because of the many years during which Stromness was the last port of call for the Company's ships on their voyages to the northwest. In a most revealing paper written but a few months before his death,[1] Dr. Wallace told how "as a boy (he) often contemplated that rugged figure (on the tomb), conveying as it did something of the indomitable vigour which characterized the man." Small wonder that those boyhood impressions should have persisted throughout his life, giving to him a love for the Northland which his duties most fortunately permitted him to exercise in good measure.

His first eight years in Canada were spent in Winnipeg, at the University of Manitoba where he was head of the Department of Geology from 1912 onwards. In 1918 he was appointed by the provincial government as Commissioner of Northern Manitoba and he held this post for three years, while on leave of absence from his duties at the University. With his wife and young family he moved up to The Pas in December 1918, and they stayed in that northern outpost until the summer of 1921. As Commissioner he represented his government in connection with almost every branch of northern life. He served as coroner, superintendent of police, mining recorder, and in many other ways. In addition to these many and varied duties, he found time to travel throughout the entire northern part of the province, including the shores of Hudson Bay. It is true that this was not in the Arctic but all who know the north will know well that the life led by the Wallaces at The Pas those many years ago differed but little from the living in points farther to the north and yet but little more isolated.

His original appointment as Commissioner was for two years but the University granted him an additional year's leave of absence before confronting him with the inevitable choice between continuing his northern work and returning to his academic duties. The decision could not have been an easy one for him to make. One can well imagine that, despite the personal reasons that must have been involved,

[1] "Rae of the Arctic", *The Beaver*, Outfit 284, pp. 28–33, March 1954.

it was to a large extent a resolving of the conflict between his love of the north and his Scottish instincts regarding education. Education won and the whole of Canada reaped the benefit but his love for the north remained, to find expression again in his final years through his service with the Arctic Institute.

His distinguished career in education is well known. His work as President of the University of Alberta from 1928 to 1936, and as Principal and Vice-Chancellor of Queen's University from 1936 to 1951 left an imprint upon Canada that will long remain. His influence for good upon the minds and characters of the innumerable young Canadians who were his students is a tale now locked away in grateful hearts throughout this land and far beyond. It is no figure of speech to say "his students", for his lectures to all first-year undergraduates at Queen's showed what manner of man this was, his most private Sunday morning visits to students in hospital being some measure of his innate kindliness.

The honours that came his way and that he so justly earned were many; they will be duly recorded in the official publications. There must have been few Canadians of his stature who carried their honours so lightly. His clear eye was as boylike and his enthusiasm as infectious, his hair just as tousled and his gestures just as youthful when the writer last saw him as they were on a happy day almost twenty years ago when he had the privilege of being the first addition appointed by Wallace of Queen's to his new staff at Kingston.

This was the man who gave up the quiet of his retirement to be the Executive Director of the Arctic Institute—as well as many other things, such as Advisor to the Ontario Department of Education, for his love for education remained paramount. He served the Institute well, almost too well for he was indefatigable in his efforts to promote this service agency for the north. He inspired the staff, he encouraged the Governors and his missionary zeal for increased scientific work in the north was transmitted to many.

Now that he has gone, regret must be widespread that he wrote relatively little. If asked, he would have said that he was too busy with people. But what he did write brings the warmth of his personality to the printed word in a quite uncanny way. So it was that, when his passing was announced, so many of his friends were reading, or had just read, a strangely moving testimony published in the *Queens' Quarterly*[1] which will long be a treasure to many. Here are words from this paper, words that tell so much of the man to whom the Arctic Institute of North America now records its great indebtedness and profound respect: "What does matter is that the human mind is not confined to the things that today are and tomorrow are gone. What does matter is that the sense of the eternal informs our doing and our thinking, that the horizon does not limit our vision, that our mind's eye can pierce beyond the things of sense into the infinity of time and of space, that we rest in the assurance that underneath are the everlasting arms."

R. F. LEGGET

[1]R. C. Wallace. 1955. "As I look back—some random thoughts". *Queen's Quarterly*, Vol. 61, pp. 490–7.